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Energy Audit of a Processing Company; A Case Study of Food and Beverages Company, Nigeria

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Abstract: In this research work, energy audit of a processing company; a case study of food and beverages company was carried out. A walk-through energy audit of the company was undertaken to identify the major sources of energy in use, identifying the lapses in energy usage, identifying areas to improve energy usage, determining the level of consumption of the energy sources and recommending policy measures that will enhance energy savings in the industries and Nigerian industries at large. From the results analysis of the energy audit, it was observed that electric motors and ovens were the major consumer of electrical energy, accounting for 30-% and 13% of total average electric energy for a period of eight years (2002-2009). Besides, electricity accounted for 80% of energy consumed, diesel accounted for 16% while manual energy was 4%. It was also noted that the company did not sufficiently utilized the energy consumption for production
Keywords: Energy audit, electricity, diesel, manual energy, processing company, consumption

I. INTRODUCTION

Energy is an essential component of a modern economy. It is an indispensible ingredient in nearly all goods and services, but its use exacts heavy financial, environmental, and security costs [1]. A key technique of reducing energy's costs while retaining its benefits is to use it more efficiently. Energy, in its various forms, is required as continuous input to all industrial processes. The total energy consumption of the industrial sectors of developed countries contributes to around 30–40 % of total energy demand [2]. In the industrial sector, energy is consumed for a wide range of activities, such as processing and assembly, space conditioning, and lighting. In total, the industrial sector uses more energy than any other end-use sector, consuming about one-half of the world's total delivered energy [3]. Electricity accounts for about a third of primary energy used by industries, with natural gas, petroleum, and coal accounting for about 128, 26 and 7%, respectively [3]. Industries also use what are traditionally thought of as energy sources for non-fuel purposes. For instance, industries such as chemicals and petroleum refining use crude oil, liquid propane gas (LPG), and natural gas as feed-stocks in producing products such as asphalt, gasoline, plastic resins and fertilizers [4].

Across the world, energy is the key input and basic need in industrial facilities for development, economic growth, automation and modernization in the industrial sector [5-6]. However, global energy demands are increasing rapidly and this concern is addressed by international researchers on how to fulfill the future energy demand. The energy consumption was estimated to increase by 33% from 2010 to2030 in the world [7]. Energy use in the industrial sector varies widely between countries and depends principally on the level of technology used, the maturity of plants, the sector concentration, the capacity utilization and the structure of subsectors [8]. Energy use in industry is likewise heterogeneous. Each facility uses a different mix of fuels for a variety of purposes in converting raw materials into saleable products. Industries vary greatly in their overall level of energy use, because of differences in their output and energy intensity (energy use per unit of output) [7].

An energy audit is defined as a systematic procedure that obtains an adequate knowledge of the existing energy consumption profile of the site, identifies the factors that have an effect on the energy consumption, and identifies and scales the cost-effective energy saving opportunities [8-9]. Energy audit is paramount in developing an energy management program. Energy audit enables one to determine where, why and how energy is being used in an industry. This audit program gives a holistic view of an understanding of the specific energy

–using patterns of a facility. Hence Energy audit will help to keep focus on variations which occur in the energy cost, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies and retrofit for energy conservation equipment [10]. Every energy audit typically involves [11]:

i. Data collection and review.
ii. Plant surveys and system measurement.
iii. Observation and review of operating practice
iv. Data analysis

Generally, there are four basic level of energy audit [12], they are as follow:

i. Type 0 audit (The Benchmarking Audit): It involves making a detailed preliminary analysis of energy usage and cost, and identifying benchmarking indices such as Btu per square foot per year and energy cost per square foot per year bases on energy bills.

ii. Type 1 (The Walk-Through Audit)**:** Is a tour to visually check each system using energy. It includes an assessment of energy usage data to analyze energy consumption trends and amounts. It also provides comparisons between similar facilities based on industry averages. It considered the least costly audit and result in a list of low-cost saving potential through improvement of operation and maintenance practice [12]. In this research work, walk through audit was adopted.

iii. Type 2 (Standard Audit): In this audit, more detailed review and analysis of the operational characteristics, systems and equipment is performed to calculate energy uses and losses [7]. On site measurement and testing is also performed as part of energy analysis to quantify energy use and efficiency of different systems. To analyze efficiencies, energy calculation and costs saving based on changes to each system, standard energy engineering calculation is used. Furthermore, economic analysis of recommended changes or measures is included in this type of audit [7].

iv. Type 3 (Computer Simulation)**:** Computer simulation audit include detail of energy use by function and more comprehensive evaluation of energy use patterns [13]. This is achieved by use of computer simulation software. The auditor will create a model of building system that will account for weather and other variables and estimate yearly energy usage. The main goal here is to build a baseline for comparison that is reliable with the actual energy usage of the subject under study. After finishing the baseline, the auditor will then try to improve efficiency of various systems by implementing different changes on the baseline model. Then the effect of these changes will be measured and compared to the base model. This type of audit also takes into account interaction between systems to avoid overestimation of savings [13].

II. MATERIALS AND METHOD

3.1 Description of the Study Area

The company used is located in Nigeria. The company has a total floor area 20,502m^2 and a treated floor area of 15,405m^2. In carrying out feasibility study in the company, I find out that there are three factories in the plant visited with each producing various products ranging from beverages, food, spring and bottled water. The raw materials used are as follows:

i. Salt
ii. Spices
iii. M.S.G
iv. H.V.P and fats
v. Sugar
vi. Ribotide
vii. Flavour
viii. Fats
ix. Caramel

x. PET (Polyethylene terephthalate)
xi. Caps
xii. Label
xiii. Tamper Proof
xiv. Shrink wrapper

The company's primary source of power supply is the Power Holding Company of Nigeria (PHCN). Nevertheless, the company has two diesel generators sets to act as standby generators. Each of these generators has a rating of 1000KVA. The factory comprises of the following equipment/machines;

i. Surface Pumps
ii. Electrical Motors
iii. Automatic Filling Machine
iv. Packaging Machine
v. Shrinkage machine
vi. Automatic capping machine
vii. Automatic filling machine
viii. Automatic washing machine
ix. Blown Moulding Machine
x. Chillers
xi. Water-dispenser filling section
xii. Compressors etc. that make uses electricity as their source of energy.

Their products include the following:
i. Foods such custards, noodles, etc.
ii. Red Wine
iii. Bottled and Spring Water
iv. Alcoholic Drinks and
v. Non-Alcoholic Fruit Juice.

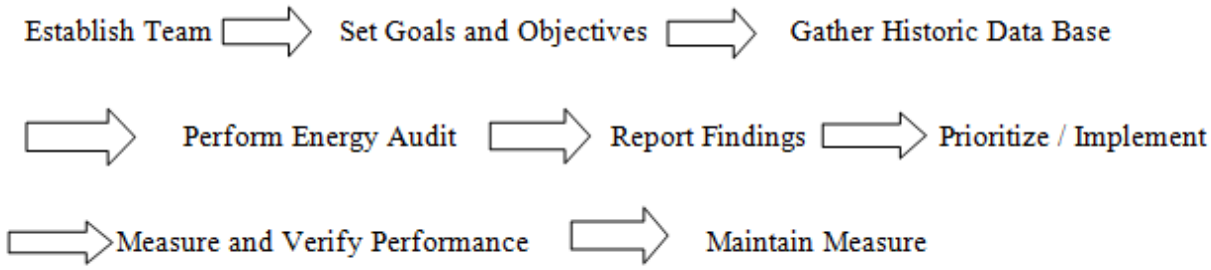
The major sources of energy used in the factory include;
i. Electrical
ii. Thermal (Diesel Fuel), and
iii. Manual

3.2 Data Collection

Data was collected from the industries under study through the following methods;
i. On-site study of all unit operations in the industries
ii. Interview of head and staff of various departments of company to obtain relevant information concerning their operation and facilities.
iii. A facility tour to obtain data of all energy systems and facilities.
iv. A review of previous works along similar line
v. Analysis of data to determine where the most significant energy saving potential is possible.
vi. Energy analysis of major energy consuming system.
vii. Preparation of report summarizing audit finding.
viii. Review of recommendation with facility management
ix. Number of occupancy/factory workers (shift) per day
x. Power rating of all machines/equipment powered by electricity

3.3 Energy Audit Process

Energy audit process requires systematic approach from the formation of a suitable team to achieving and maintaining energy savings. A typical energy audit process is outlined below:



3.4 Data Analysis

From the data collected, the following procedural steps were taken to get them analyzed and presented in the required forms:

i. Energy types (electricity and fuel) were identified and collated
ii. Annual consumption for each type was determined
iii. The percentage breakdown of total consumption was calculated
iv. The energy use ratio of each company per year was determined to establish energy utilization pattern
v. Energy productivity in GJ/kg was determined

3.5 Energy Evaluation

3.5.1. Evaluation of Electrical energy

The electrical energy input in is obtained by multiplying the rated power of the electrical motor, in with the corresponding hours of operation.

$$E_p = \eta P t \quad (3.1)$$

where,
Ep = Electrical energy power input (kwh)
η = the motor efficiency = 80% [14]
t = hours of operation
P = Power (kw)

3.5.2 Evaluation of Thermal Energy

The thermal energy input was calculated based on quantity of fuel used to generate steam in the boiler. The quantity of fuel in litre is converted to joule by multiplying the quantity consumed by corresponding calorific value, of fuel.

$$E_f = C_f \times W \quad (3.2)$$

where,
Ef = Thermal energy input (J)
C_f = Calorific value of fuel (J/L)
W = Quantity of fuel

3.5.3 Diesel Fuel Consumption

Diesel fuel consumption is given by Equation (3.3)

$$E = m_{fu,d} \times cv_{fu,d} \quad (3.3)$$

where,
E = Diesel fuel energy consumption
$m_{fu,d}$ = Mass of diesel fuel (kg)
$cv_{fu,d}$ = The calorific value of the diesel fuel (kJ/kg)

3.5.4 Manual Energy

Manual energy input was estimated based on the maximum continuous energy consumption rate of 0.30kW and conversion efficiency of 25% [15]. As reported by Odigboh [15] and Norman [16], the physical power output of a normal human labour in the tropical climate is approximately 0.075kW sustained for 8-10h workday.

$$E_m = 0.75Nt \quad (3.4)$$

$$E_{mf} = 0.68Nt \quad (3.5)$$

E_m = Manual energy input for a male worker (kWh)
E_{mf} = Manual energy for a female worker (kWh)
N = Number of persons involved in the operation
t = Useful time spent to accomplish a given operation

3.5.5 Total Energy Input

For each unit operation the total energy input is given as:

$$E_T = E_p + E_f + E_m \quad (3.6)$$

E_T = Total energy input
E_p = Electrical energy power input (kwh)
E_f = Thermal energy input (J)
E_m = Manual energy input (kWh)

III. RESULTS AND DISCUSSION

TAnnual energy consumption and production output for the company for a period of eight (8) years (i.e. 2002-2008) is shown in Table 1.

Table 1 Energy Consumption and Production Out for the company

S/N	Year	Source of Energy							Production
		Electricity (PHCN)		Diesel		Manual		Total	
		kWh	GJ	Vol.(ltr)	GJ	No	GJ	GJ	(kg)
1	2002	3437455.0	12375.838	63412	2392	98	596	15362.84	12498
2	2003	3428556.5	12343.8034	64523	2434	108	657	15434.80	13597
3	2004	3398958.9	12236.2520	63523	2396	115	699	15331.25	13126
4	2005	3418057.2	12305.0059	65123	2456	125	760	15521.00	12384
5	2006	3426758.0	12336.3288	63145	2382	126	766	15484.33	12567
6	2007	3339675.9	12023.8332	62987	2376	110	669	15068.83	13234
7	2008	3405674.7	12260.4289	64513	2433	95	578	15271.43	12985
8	2009	3410985.8	12279.5488	62556	2359	85	517	15155.55	13675

The used data as shown in Table 1 presented the annual energy consumption and production output for a period of eight (8) years (i.e. 2002-2009). The highest total energy consumption was obtained as 15521GJ which was the year 2005 while the total lowest energy consumption was recorded as 15068.83GJ which was the year 2007. For production in tonnes, the highest was obtained as 13675 tonnes in the year 2009 while the lowest recorded as 12384 in the year 2005 despite the huge amount of fuel consumed.

The comparison of yearly energy consumption using electricity (PHCN), thermal (Diesel), and manual (Human) is shown in Table 1. Throughout the period of this research work, electricity (PHCN) has the highest quantity of energy consumed from year 2002-2009. The reason for this was as a result of electricity rotational system that favours company, industries, and firms during the working hours of 8am-5pm. This followed by thermal energy (Diesel) and manual which is powered humanly came least. Table 2 and Figure 1 show the summaries of the average and pie chart of average percentage energy consumed for the period of eight (8) years.

Table 2 Average Energy Consumption

S/N	Year	Energy Source		
		Electricity (GJ)	Diesel (GJ)	Manual (GJ)
1	2010	12375.8380	2392	596
2	2011	12343.8034	2434	657
3	2012	12236.2520	2396	699
4	2013	12305.0059	2456	760
5	2014	12336.3288	2382	766
6	2015	12023.8332	2376	669
7	2016	12260.4289	2433	578
8	2017	12279.5488	2359	517
□	8	98161.039	19228	5242
Average	1	12270.130	2403.5	655.25
Total Average		**15328.88**		
Percentage	**100**	**80.05**	**15.68**	**4.27**

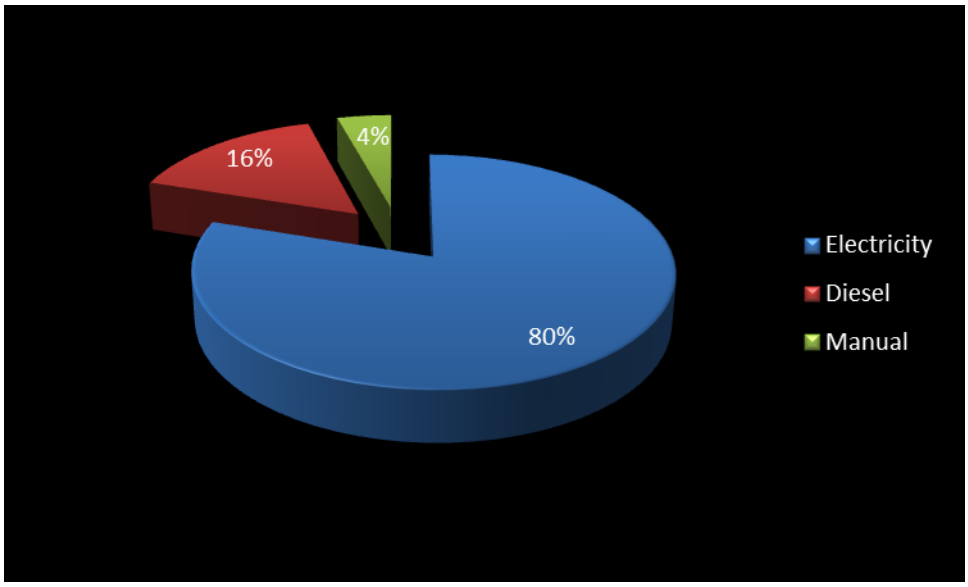


Figure 1: Average percentage of energy consumed for the period of eight (8) years

From Table 2 and Figure 1, manual energy consumed in operating machines and lifting of loads was found to be the least consumer of energy accounting for just 4% (on average) of the total energy input on for the eight (8) years period of used in this research work . Electricity (PHCN) was the most consumed accounting for 80% of total energy consumed. Diesel fuel energy expended in operating diesel engine was the second highest consumed source of energy and it accounted for 16% on average. The patterns of electrical energy consumption by various company equipment/machines used for manufacturing and processing is shown in Table 3 and Figure 2.

Table 3: Electrical Energy Consumption of Equipment/Machines

Equipment/Machines	Percentage Energy Consumption (%)
Surface pumps	3
Electrical Ovens	13
Automatic Filling Machines	3
Packaging Machine	2.5
Shrinkage machine	5
Automatic capping machine	1.5

Automatic filling machine	2
Blown Moulding Machine	6
Automatic washing machine	3
Chillers and Boilers	10
Compressors	8
Air conditioners	6
Lightening	2
Miscellaneous	5
Electrical Motors	30
Total	**100**

As shown in Table 3 and Figure 2, out of 15328.88GJ of total average energy consumed in for a period of eight years production, electrical motor accounted for highest electrical energy consumption (30%), followed by oven which is 13%, chillers, compressor, and air conditioners accounted for accounted 10%, 8%, and 6% respectively. Furthermore, miscellaneous this comprises of standing fans, ceiling fans, television sets, refrigerators, etc. accounted for 5% of the average total energy consumed within the period.

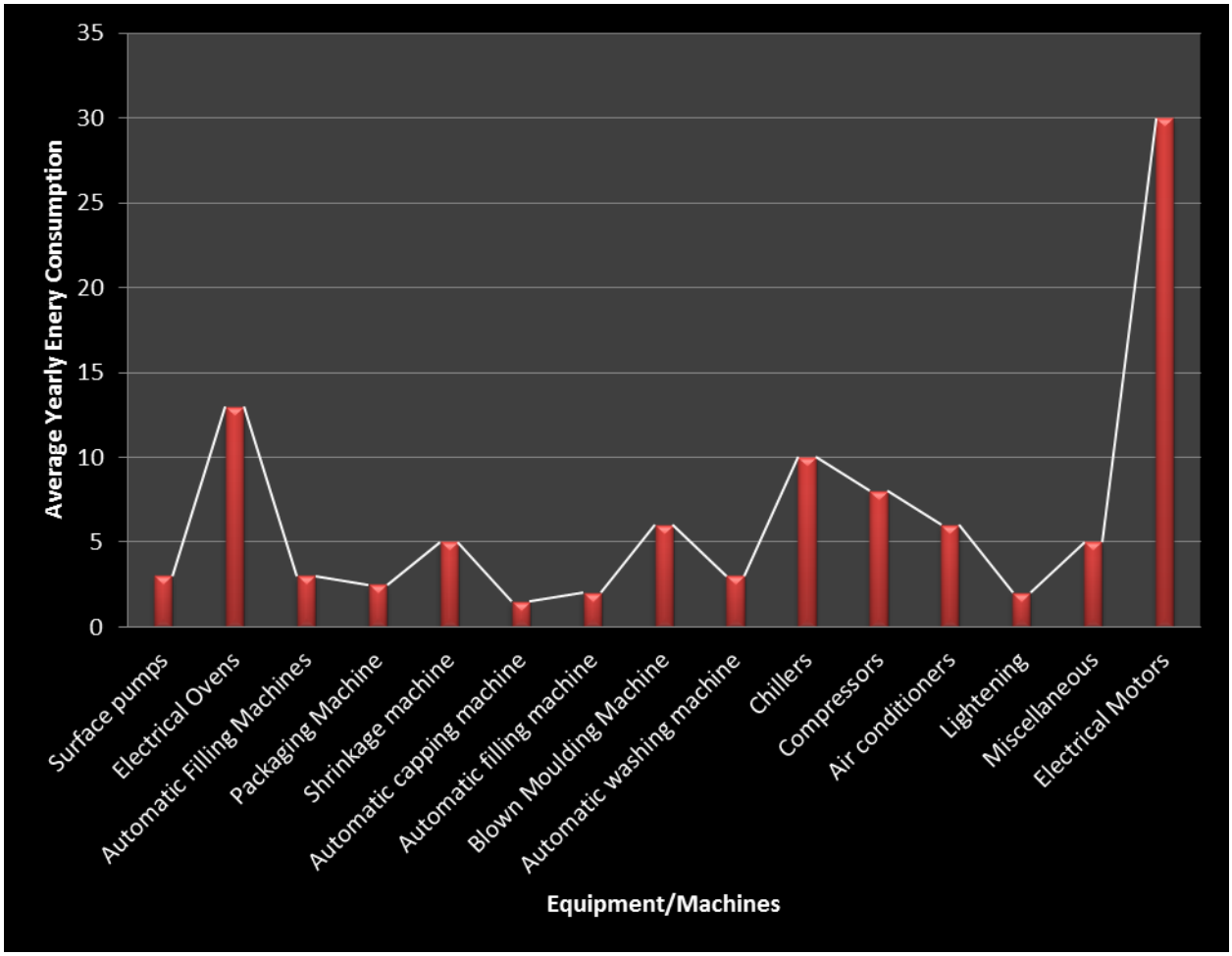


Figure 2: Electrical Energy Consumption of Equipment/Machines

From walk-through energy audit carried out, it was observed that the environmental needs in an industrial operation can be quite different from residential or commercial operations. At the company environment, it was observed that air- condition and refrigeration equipment were dirty and dissipating much heat. It was also observed that there was no minimum temperature setting for air conditioners and refrigerators so that staff can use it for regulating their temperatures.

IV. CONCLUSION

In this research work, energy audit of a processing company was carried out. The pattern of energy consumption identified the sources of electrical energy waste and assessed the effectiveness of the strategies for electrical energy savings in the company. The sources of energy in the company surveyed comprise of manual, thermal (diesel) and electricity (PHCN). The percentage of electric energy consumed from PHCN is 80%, thermal (diesel) is 16%, and manual is 4%. The areas of most waste energy and where actions for energy conservation can be implemented have been identified. Energy use lapses identified in this study were due to lack of good energy conservation practices (such as replacing worn out engine parts), diesel leakage, steam leakage from steam pipeline and ageing of machines/equipment. The results of the analysis made over the period of eight years showed that energy was not efficiently utilized at the companies. The results of the energy productivity shows that production did not justified energy consume in some of the years especially the year 2013

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