

Full Length Research Paper

Assessment of electrical energy use efficiency in Nigeria food industry

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Accepted 28 July, 2020

This study examined various patterns of energy consumption; it identified the sources of energy wastage, and assessed the effectiveness of the strategies that were employed to reduce energy waste in the food companies. This was with a view to recommending policy measures that would enhance effective electrical energy savings in the industry. Random sampling technique was used to select the food companies in South-western Nigeria which represent more than 50% of the Nigerian food and beverage companies. Structured questionnaire, interview and direct observation were employed as research instruments. Analytical procedure as given by Knutson and ANSI/NEMP for calculating electrical energy lost to heat per hour (Wh/h) and power factor respectively was adopted for the study. The study showed that the pattern of electrical energy consumption in the food companies was mainly from generating set; this was due to either low voltage or epileptic power supply from national grid. Direct and indirect sources that lead to electrical energy waste and in-efficient energy utilization in the industry were identified such as energy loss as a result of worn out or slack / misaligned belts that need timely replacement or tensioning, training and retraining of staff, power factor of electrical equipment among others. Three out of eleven strategies were effective in reducing the companies' electricity bill by 3% for the same quantity of production. These include: switching off most lighting during day time; instant replacement / tensioning of worn out / slack belts or chains and; disconnection of all faulty equipment. This finding shows that 72.8% of all the acclaimed strategies to reduce energy consumption were not effective. The study concluded that the factors that constituted electrical energy waste and energy use inefficiency in the food companies in the study area were very identical and recommendations for effective energy use efficiency in the firms were proposed.

Key words: Electrical energy, efficiency, energy waste, food industry, Nigeria.

INTRODUCTION

Energy for obvious reasons is regarded as the prime mover of any economy, and the engine of growth around which all sectors of the economy revolve. Thus, it becomes imperative that its development, management, and improvement must have predetermined plans and strategies that are capable of driving the economy towards a sure path of sustainable development (Jesuleye, 1999). West African region has one of the lowest per capita consumptions as far as energy is concerned. On the other hand, the energy-GDP ratio of most of the countries in

the region is higher than those of developed nations (Adegbulugbe, 1991).

Although, energy has been a major driver for human and technological development, it has also contributed to local and regional environmental degradation and more recently, to global environmental threats (Energy and Development Research Centre- EDRC, 2002). Moreover, electricity-generating capacity in Africa with respect to the population is low. For instance in 1997, it was only 94 GW which was only 3% of the global total (EDRC, 2002). Nigeria's energy demand has increased much more rapidly than its population (Akarakiri, 1990).

The consumption of energy, especially fossil fuels, releases CO₂ into the atmosphere. This has made the

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energy sector to be recognized as the largest source of CO₂, which is the most important of green house gases (GHG) emissions globally. GHG has attracted worldwide concern because of their effects on the environment, especially the climate (Adegbulugbe et al., 1994). Another hidden feature in the development and utilization of energy is the environmental implications of energy production and use.

At the World Energy Summit in Kyoto, Japan in December 1997, a consensus was reached that legal action should be adopted for the abatement of CO₂ emissions associated with inefficient use of energy (Eyre, 1998; Jesuleye, 1999).

In most of the developed countries, the food processing industry provides an important link between the farmer and the consumer (Singh, 1986). This industry is vital to assure a uniform supply of foods throughout the year. Operations such as sterilization, freezing and drying assist in minimizing product losses during handling and storage. During the last several decades, introduction of mechanization to achieve high processing capacity has caused the food industry to depend more heavily on energy obtained mostly from petroleum products. Before mid-1970s, in many industrial nations, the comparative low price of fuel in the past discouraged any emphasis on energy conservation in design and operation of food processing equipment (Singh, 1986).

Industries generally use various energy sources such as oil, gas, coal, solar, nuclear, wood-fuel and electricity in the process of their final product. Food industry requires energy for a variety of equipment, such as gas-fired ovens, dryers, steam boilers, electric motors, refrigeration equipment, heating, ventilation and air-conditioning systems. In food industry, the principal type of energy use includes electricity among others. Two-thirds of electric consumption is used in generating mechanical power to operate conveyors, pumps, compressors and other machineries. Purchased electricity accounts for about 13% of the gross energy consumption in the nineties, and industries associated with fluid milk processing, frozen fruits and vegetables, depend mostly on electricity (EDRC, 2002). However, the food manufacturing companies in Nigeria use electricity for virtually all their daily activities especially in the area of machinery and instrument operation during production. This electrical energy is obtained either directly from national grid or from company's stand-by diesel-powered generating set.

The problem

Research has shown that food industry wastes energy in areas such as boiler plant, service water reduction, air handling system, room conditioning unit (Energy Institute Press-EIP, 2003), self-contained heating ventilation and air-conditioning (HVAC) equipment (Energy Book-EB, 2003), building air leakage, poor control and use of sunlight, artificial lighting, independent energy-using com-

ponents, among others (Wulfinghoff, 2003).

The problems discussed above have greatly contributed to high cost of production in the Nigeria food industry. Though the extra costs are passed unto the helpless consumers, these products lose the competitive advantage when placed side-by-side with their foreign counterparts.

The following questions prompted this study: How is energy used in food industry? How is energy saved/wasted in the food industry? What is the energy saving technologies/devices used in the food companies in South-western Nigeria to minimize energy losses? What are the best areas for reducing energy consumption in electrical equipment? And to what percentage can food industries reduce their energy bills?

The specific objectives of this study were therefore to examine the pattern of energy consumption in selected food companies in South-western Nigeria; identify the sources of electrical energy waste in food industry; assess the effectiveness of the strategies for electrical energy savings in the industry, and develop appropriate strategies for effective energy savings in the industry.

METHODOLOGY

The data for the study were collected from 210 randomly sampled micro and small-scale food and beverage companies contained in the publication of the ISIC in South-western Nigeria. The Companies belong to the following sectoral groups: beverage and tobacco products, pure water processing and packaging, palm oil processing, bakery products, grain mills products, and cold rooms. The study employed the use of structured questionnaire, oral interview and direct observation techniques. Secondary data source from private and government publications (published and unpublished) were also used. The questionnaire and oral interview were for business owners, production managers, utilities or factory managers or engineers and workers within the production section of the food companies in the study area. The information that was gathered was sorted, edited and coded. The Statistical Package for Social Sciences (SPSS) was used for the data analyses. Descriptive statistics was used for data analysis.

RESULTS AND DISCUSSION

Categories of firms surveyed

Table 1 shows five categories of food and drink companies surveyed at state level in Nigeria. These firms include beverage, bakery, grain-mill, cold food and sachet water. Most of the enterprises were into beverage production and bakery.

Pattern of electrical power supply

Analysis of the survey revealed that while 89.7% of the respondents used generator as an alternative power supply, 10.3% of the respondents that depended solely on the national grid for the supply of electricity did so

Table 1. Percentage response rate by the food and drink companies in the study area.

State	Beverage	Bakery	Grain mill	Cold food storage	Sachet water	% Response
Lagos	36	30	-	-	-	73.3
Oyo	36	-	6	-	-	87.5
Ogun	6	12	-	-	-	75.0
Ekiti	-	12	-	-	6	100.0
Ondo	6	6	6	-	-	100.0
Osun	-	6	-	6	-	100.0

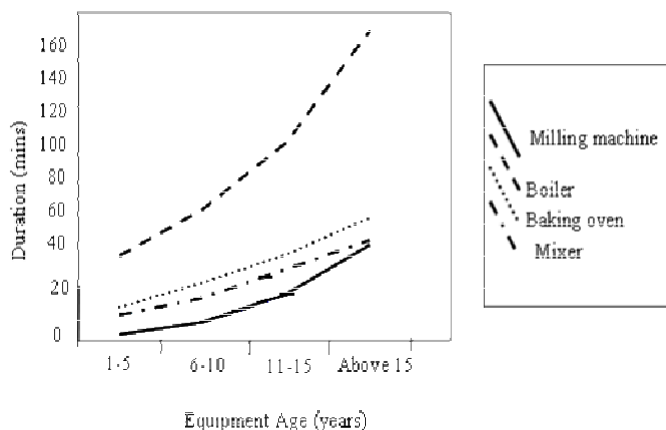


Figure 1. Electrical equipment and pattern of electrical energy consumption sources of electrical energy waste in the industry.

simply because their generating sets were spoiled and they could not afford the cost of their repair. During production, the former runs generator whenever there was either power failure or low voltage supply (usually less than 10% of the equipment rated voltage). This was often done so that their electrical equipment could run cooler and more efficiently.

Equipment age and the pattern of electrical energy consumption

More than thirty-nine percent (39.1%) of the electrical equipment used in the selected food industry in the study area were well above 15 years in age. The equipment became less efficient due to wears in some of their parts. As a result, the quantity of product that was fed into them was reduced by 30 to 40% before the machine could run. In some cases, the processes were re-run twice or thrice before achieving the final specification. This, no doubt consumed more energy than necessary.

Again, the type of maintenance practice used for the machine was also another contributory factor to their energy use efficiency. The electrical equipment investigated were milling machine, boiler, baking oven and mixing machine. Figure 1 shows that the higher the equipment age, especially those equipment under improper maintenance, the longer the time it took to carry out

specified production process as the case may be. Twelve components (labeled A to L) constituted ways by which electrical energy was either lost or wasted in the food industry. Table 2 shows the percentage of response on the sources of electrical energy wastage or loss in the companies.

Slack/worn out belts or wear on gear teeth resulting on excessive backlash

Belt/chain in its normal position and tension around pulley/sprocket was at a preset angle; it discharged its duty of rolling its subject with little or no transmission loss. Reduction in this angle typified that the belt/sprocket was either sag or slack; and belt in this position was bound not to deliver its expected driving capacity. Excessive sag of belt results to belt sliding over and around pulley groove, thereby generating heat between the belt and the pulley. The driven mechanism therefore required more time and energy to accomplish a specified production process. Tensioning of the belt /sprocket or complete replacement (for worn out ones) was a better option to minimize the energy waste.

Undersized main supply cable

Types of load determined, to a large extent, the size of electrical cable to be used for installations. However, in some cases, cables of 6 mm² diameter were used to supply a utility building where a total current drawn (after putting diversity factor into consideration) was above ninety amperes. Such cabling system was bound to heat up or even got burnt especially on full load, leading to indirect loss of useful energy. The advisable thing to do was to consult registered electrical engineers as well as insisting on IEE standard both in material quality and design when electrical-mechanical installations were done.

Leakage from ovens, refrigerators and other drying or cooling equipment

Leakage from doors, ovens and similar equipment was

Table 2. Sources of electrical energy waste in the firms.

S/no	Ways by which electrical energy is wasted in food industry	No. of firms	%
A	Slack or worn out belts.	72	41.4
B	Generated heat on (or from) electrical machine in use.	102	58.6
C	Undersized main supply cable.	60	37.0
D	Air leakage from ovens, refrigerators and any other drying and cooling equipment.	54	33.3
E	Poor control of sunlight towards having negative effect on company's architecture.	54	31.0
F	Lack of usage of sunlight as an alternative to purchased electrical energy.	12	8.3
G	Lack of usage of the heat generated from a cooling system.	54	31.0
H	Worn out pulleys.	48	29.6
I	Wear on gear teeth resulting in excessive backlash.	30	17.2
J	Wear on drive sprockets/ slack chain.	60	35.7
K	Failure of couplings/ misalignment.	66	39.3
L	Lubrication failure in gearboxes resulting in failed bearing or gear teeth.	66	40.7

equal to indirectly loading the system. It was also similar to increasing the space with which the oven was expected to heat. This happened whenever door seal or lining was cut, or there were holes on the system walls. Therefore, weak or cut seals and linings must be replaced and all holes blocked to minimize energy that was wasted or lost due to the above.

Poor control of sunlight / lack of usage of sunlight as an alternative to purchased electrical energy

Sunlight is a free God-given energy source that could have been maximally utilized, but was being wasted because of the unaffordability of its processing kit. Also, as a result of poor architectures, which allowed more than needed sunlight rays into the factory; the accumulated heat served as additional load of heat that needed to be ejected by air-conditioner. The availability and affordability of solar energy processing kits would go a long way to the utilization of the free energy source in the nation's industrial sector.

Lack of usage of the heat generated from a cooling system

In the developed nations, heat recycle was a normal phenomenon. The heat generated from air-conditioners, cold-rooms, among others, in the food industries was left to waste away unnoticed. This heat could either be reprocessed, converted and stored to drive another production process or could be used directly to heat water for domestic purposes, thereby minimizing energy cost for the industry.

Worn out pulley/wear on drive sprockets and slack chain

One of the characteristics of a good pulley is perfect

roundness (concentricity). When pulleys lost their concentricity and became wobbling, or their grooves were damaged, friction and over-tensioning of belt results. This was the situation in some of the firms that led to energy being wasted, lost and inefficiently managed. Such pulleys destroy belt in no time either by cutting or weakening it as the case may be, due to much friction. The situation was similar in the case of sprockets. Reductions in the amount of energy expended to drive such equipment were experienced as soon as the pulleys / sprockets were replaced by appropriate ones. Furthermore, failure of couplings and misalignment was another source leading to energy loss in the industry.

Lubrication failure in gearboxes resulting in failed bearing or gear teeth

In all mechanical machines assemblies, bearings and gear boxes of various types and sizes were engaged for their effective and perfect running. These gear boxes and bearings last longer and functioned well mostly in the presence of regular and adequate lubrication. Whenever oil / grease dried up inside them, their balls or gear teeth were engaged in unnecessary frictions which resulted in heat loss through their heated-up housings. Also, more energy was needed to roll the stiff and un-lubricated systems. Therefore, reduction in energy consumption in these areas required that constant lubrication in all gear boxes and bearings be ensured.

Level of staff education and experience

Experience cannot be bought with money; it is often acquired over-time. The 'over-time' is on how long the staff has been performing the given official duty, coupled with the frequency and type of on-the-job training such staff is exposed to. Meanwhile, in a nation like Nigeria where paper qualification is usually the determinant

Table 3. Level of education.

Title	Tertiary	%	Secondary	%	Primary	%	Non-formal	%	Total
Owner	138	79.3	36	20.7	0	0.0	0	0.0	174
Management Staff	528	81.5	120	18.5	0	0.0	0	0.0	648
Supervisor	78	46.4	90	53.6	0	0.0	0	0.0	168
Operator	30	19.2	126	80.8	0	0.0	0	0.0	156
Others e.g Driver	0	0.0	54	39.1	42	30.5	42	30.5	138
Total	774	60.3%	426	33.2	42	3.3%	42	3.3%	1284

factor for nominating staff on the frequency, type and relevance of seminars / conferences one is sent for, then staff level of education forms a basis in the acquisition of relevant job experience.

The 174 respondent firms had a total of 1284 staff having title ranging from business owner, management staff, supervisor, operator and other cadres such as drivers, security and their educational qualification as tertiary, secondary, primary and informal educations. From Table 3, the number of staff that fell within the categories of tertiary, secondary, primary and informal education was 774(60.3%), 426(33.2%), 42(3.3%) and 42(3.3%), respectively. However, with more critical look at the table with respect to the title and the educational level of those who were directly involved in the production, the reverse was the case. Thus, in a further breakdown of the 174 business owners, 138(79.3%) were graduates of tertiary institutions while the remaining 36(20.7%) had secondary school as their highest qualification. Again, out of six hundred and forty eight management staffers that responded, 528(81.5%) had tertiary education while the remaining 120(18.5%) stopped at secondary education level.

Meanwhile, out of 168 supervisors, 78(46.4%) were tertiary institution graduates while 90(53.6%) had only secondary school education. Having more than half of the supervisors with secondary school education could lead to electrical energy wastage in the firms because half-baked/ignorant supervisor would lack knowledge of proper inventory keeping of production process data. The supervisor, because of inadequate education and experience, may not be able to convincingly instruct security personnel as to when to switch on or off outdoor lightings. Energy would equally be wasted if supervisor did not know what to do when an operator gave him report that electrical motor casing was excessively hot, or when there was arching whenever switch gear was operated or when many halogen lamps were installed as security light instead of fluorescent lamps or when operators were talking leaving machines running or when the standby generator was left running even after switching over to national grid. In a situation where higher percentage of factory supervisor was unknowledgeable or ignorant or less educated, more useful electrical energy would be wasted.

Furthermore, out of 156 operators, 30(19.2%) were tertiary institution graduates while 126(80.8%) stopped after their secondary school education. The inexperienced, less educated operators wasted more energy during production either by leaving machine running when they are supposed to be switched off, or leaving computer systems in standby mode when they should be switched off. The operators' action may not be intentional but are occasioned by ignorance that every unit of energy wasted in production drains factory purse by some amount of naira, which invariably affects product cost thereby making the product more expensive than its counterparts whose factory had energy-management-oriented-operators who avoided all energy waste before, during and after production.

This result agreed with the previous research of AGEM in 1993 at the University of Bristol on ways of reducing energy waste at home and at work (EEMU, 2004).

Moreover, out of the 138 respondents grouped under 'other staff', 54(39.10%) of them had only secondary school education, 42(30.45%) had only primary school leaving certificate and the remaining 42(30.45%) were working without formal education. This no doubt served as source of energy waste in the firm where these set of people were working. Useful energy was wasted whenever security personnel 'forgets' to switch off security lights in the day time; also, energy (money) was wasted by ignorant / unknowledgeable driver either by allowing vehicle inner light on unnecessarily or putting on vehicle head lamps in the day time or leaving vehicle radio on when engine was not running in the absence of passengers. This energy could be saved if the personnel were knowledgeable.

Training and retraining of staff

The study verified whether training and retraining was a significant parameter for energy saving in the firms. Sixteen percent of the firms conducted training monthly, 32% conducted training quarterly, and 28% yearly while 24% did not conduct training for staff at all. This result suggests that training and retraining did not directly constitute a source of electrical energy waste in the industry since only a low (24%) percentage of the firms

Table 4. Power factors of the electrical equipment used by the firms.

Motor type	0.95-1.0	0.85-0.94	0.75-0.84	0.65-0.74	0.55-0.64	0.45-0.54	Sub total	Total	%
(Big) 3 phase variable	0	0	0	24	12	0	36		
Const.	0	0	6	6	0	0	12	48	28.6
(Medium) 3 phase variable	0	0	0	0	0	0	0		
Const.	0	0	6	18	0	0	24	24	14.3
(Small) 3 phase variable	0	0	0	0	6	0	12	12	7.1
Const.	0	0	0	6	0	0	0		
(Small) 1 phase variable	0	0	6	12	6	6	30		
Const.	0	0	12	18	12	12	54	84	50
Total	0	0	30	84	36	18	168	168	100

do not conduct any training for their staff.

Lighting systems

Out of 312 lighting systems found in 174 firms, 150(48.1%) of them were incandescent lamps ranging from 40 to 200 watts, 54(17.3%) were halogen lamp ranging from 500 to 5000 watts, fluorescent and energy-efficient bulbs that were known to be energy efficient lighting systems were 102(32.7%) and 6(1.9%) respectively. This showed that much energy was being consumed and invariably wasted. However, rationing between electricity and generating set was the most frequently used energy saving method meant to improve production efficiency by most of the organizations; followed by disconnection of faulty equipment (6.1%) replacement of slack belts (6.1%) and switching of lighting system in the day time (6.1%). About 45% of respondents claimed that there was reduction in electricity consumption as a result of the adoption of some of these energy saving methods; while 55% reported no reduction.

Power factors of the electrical equipment used by the firms

This is the fraction of the total amount of electrical equipment, which is effective in producing power. Though the rest of the current is not effective in producing power; it must flow through the motor, producing added heat (energy loss). From Table 4, out of the 174 firms, 168 (96.6%) indicated the power factor on their electric motor. Electric motors were divided into 3 major sizes with the number of firms using them as follows; small 96(57.1%), medium 24(14.3%) and big 48(28.6%).

The small electric motor was further divided into single (1) and three (3) phase categories. Out of the 96 firms that used small electric motors, 12(12.5%) and 84(87.5%) were 3-phase and 1 phase, respectively.

However the big and medium size operated only as 3 phase with 28.6 and 14.3% firms, respectively. Furthermore, the electrical energy lost to heat per hour (Wh/h) was equal to (total current)² x resistance (A² =Watts). This current either lags or leads the electric motor voltage by 90 degree. Most alternating current motors have a lagging power factor ranging from 0.5 to 0.9 (the ideal power factor is 1.0; Knutson, 1981).

The range of power factor in unity from Table 4 was 0.45 to 0.54, 0.55 to 0.64, 0.65 to 0.74, 0.75 to 0.84, 0.85 to 0.94 and 0.95 to 1.0. From this table, the number of firms in the categories was 18(10.7%), 36(21.4%), 84(50%), 30(17.9%), 0(0%), and 0(0%) respectively. Also, the speed of the electric motor was sub-divided into those with constant and variable speeds. Out of the 168 firms, 78(46.4%) used variable speed motors ranging from small to big sizes while 90(53.6%) firms used constant speed electric motor.

Hence, as shown in Table 4, if the power factor were improved from 0.45 to 0.54, the 18 firms would save considerable amount of naira. Similarly, improving power factor from 0.55 to 0.64 and 0.75 to 0.84, would lead to much money being saved by 150 firms, less energy would be wasted, electrical equipment would be more efficient and consequently the firms' products could sell at lower price thereby making the products more competitive among its counterparts both locally and internationally.

Furthermore, from personal interview and measurement that was carried out in some of the firms during the field survey, three categories of electric motors with different capacities were represented by Figure 2. These were one, five and ten horsepower motor capacities. The scales were also chosen thus; percentage power factor represents y-axis (having scale zero to ninety) and percentage load efficiency represents x-axis (with scale 0 to 125) . The varying voltage and current represent low voltage supplied, among others. Since power factor is rarely listed on the nameplate, it is therefore determined using equations 1 and 2 for single and three phases respectively (ANSI/NEMP, 2002) as shown below.

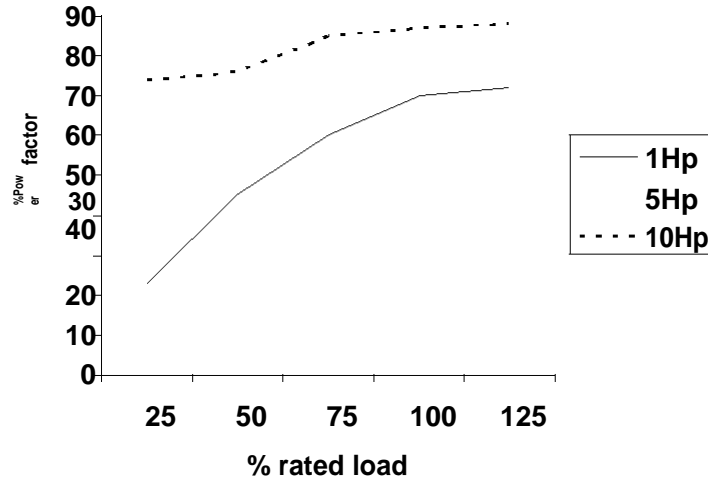


Figure 2. Power factor versus load curves for 1800-RPM three-phase 50-Hz design squirrel-cage induction motors.

$$F = 746P/VE \quad (1)$$

$$F = 431P/VI \quad (2)$$

where F is the per unit power factor (per unit $F = \%F/100$) at full load; P rated horse power (hp); V rated voltage (V); I rated current (A); E per unit nominal full-load efficiency (per unit $E = \%E/100$).

When equation 2 ($F=431P/VI$) was applied; then F was 0.55. Similarly, at P = 10 horsepower, V = 410V, I = 13.21A and E = 90%, F was 0.88.

The figure further shows that at the point where percentage power factor of motors 1, 5 and 10 horsepower were 23, 60 and 74, respectively, their percentage rated load was 25.

Similarly, at percentage power factor of 70, 78 and 87 for 1, 5 and 10 horsepower motors, their percentage full-load efficiency was 100. The low percentage power factor was as a result of low supplied voltage from the national grid most of the time. And since the lower the power factor of an electrical machine, the inefficient such machine would be in terms of energy utilization.

For instance, a 3-phase motor has the following measured information: horsepower was 10, supplied voltage was 367Volts, and the motor draws 23.64 Amperes. Its percentage full-load efficiency was 90.

Designed / input motor voltage

The 174 firms had a total of 390 electric motors using electricity. Two hundred and eighty-two (72.3%) of the motors were single-phase with designed voltage of 220V. The 282 single-phase motors were sub-grouped into five different voltage ranges. The supplied / input voltage for single phase could be broadly divided into 2 categories; those with supplied voltage less than 200V and those with 201V and above. Two hundred and sixteen (76.6%),

(that is, the addition of 30, 84 and 102) of the motors had input below 200V while 66(23.4%) were operating at input voltage of 200V and above. This showed that majority of electric motors were operating at low voltage which invariably could lead to inefficiency on the performance of the motors and this could cause electric motor / machines / equipment to draw more current and thus increase energy consumption, leading to excessive heating of the electrical system. This confirmed the reason for energy waste, inefficient use of electrical energy and high electricity bill in the industry.

Similarly, voltage in the range of 415 and 11000 was also sub-grouped. In this category, 96(24.6%) out of 390 respondents had 3-phase motors, 72(75%) of the 96 were operating at voltage below 0.40kv while 24(25%) operated above 400V. Furthermore, 12 firms using electrically controlled motors of high-voltage operated below 11000V rated voltage. From the above observations, electricity bill would be high; also, life span of machine / equipment using electric motor would be drastically reduced due to excessive heat generated as a result of un-utilized energy and high current flow. Moreover, for confirmation, all the 390 electrically controlled motors were grouped into two, that is, those operating below rated voltage ($216+72+12 = 300$) were found to be 76.9% and those within the rated voltage were 90(23.1%). Evidently, this showed the reason why electricity bill was high.

In addition, Elliot et al., (2005) reported, that in United States of America, fan, pump and electric motor accounted for more than a quarter of industrial electricity consumption nationally. And if majority of these motors were old standard energy inefficient types, about 19% additional cost would be incurred in fueling the inefficient generator in the first place, and consequently much energy would be consumed in using the generator to power the large number of old standard fans, pumps and

motors.

Maintenance practice

The frequency of service maintenance carried out on the equipment as a function of number of hours such machine had been engaged for production was investigated. About 18% of the firms carry out service maintenance monthly, 39.3% carry out maintenance quarterly, 17.9% perform service maintenance yearly, and 21.4% perform maintenance during breakdown while 3.6% does not carry out service maintenance at all. In addition, about half of the respondents performed corrective maintenance while the remaining half practiced preventive maintenance. The assumption was that a machine that is engaged in a normal production process within a space of three months would have covered the required running hour expected of it before it can be said to be due for servicing. This result showed that maintenance practice was not a source of electrical energy waste in the industry.

Up-to-date process database

About 36% of the firms had up-to-date process database while the remaining 64.3% have inconsistent database. This could constitute a source of electrical energy waste in particular and inefficient electrical energy use in general in the industry because lack of knowledge of previous data on the required electrical energy needed for a specified production process could make staff to leave the machine running unnecessarily. In addition, those firms that kept up-to-date database did so for the increment of their present capacity and not for the purpose of reducing electrical energy consumption or equipment efficiency.

Strategies for electrical energy savings and effectiveness

Out of the 174 firms, 102 (65.4%) believed energy should be saved while 6(3.8%) believed it should be recycled. Meanwhile, the following methods were employed in saving electrical energy in the food companies.

Minimizing consumption

The twelve (6.1%) companies that were using this method placed embargo on leaving any of the production machine or equipment unnecessarily.

Restriction of electricity consumption

The use of air-conditioners during harmattan season was

prohibited especially in most of the administrative offices; similarly, all interior and exterior lights were switched on only when needed.

Bulk operation

The operation managers were instructed not to start machine for production in response to bit-by-bit placed-order from the customers; but should always persuade these customers to be patient until the company has received sufficient orders.

Rationing between electricity and generating plant

The seventy-two (36.3%) companies that were using this method to save electrical energy consumption in their establishment educated their staff members not to run generator every time there was power outage, except on two occasions such as power outage during production and at night before closing for work.

Switching off lighting systems in daytime or when not in use

All staff members in the companies where this method was practiced were instructed to always make sure that lightings in their offices were switched off during daytime. Also lightings in the shared rooms such as toilets, inventory stores, among others, should be switched on only when needed.

Replacement /adjustment of slack belt

Both operation managers and machines operators were advised to daily carry out thorough inspection on their machine and equipment before and after production. This will enable them replace all cut / wounded belt, worn-out sprocket / gear teeth or adjustment is made on slack belts / chains.

Disconnection of faulty equipment

All equipment / machines that have one problem or the other were isolated from getting electricity supply to avoid the mistake of being switched on.

Preventive maintenance

The 6 (3.0%) companies that used this electrical energy saving method emphasized it to the concerned staff on the need to always carry out the maintenance of their machines / equipment as at when due.

Using sized cable

The production engineers of the 6 companies recommended the use of right sized cable between the terminal points and their utility buildings especially for all fresh installations. This enabled the cables to carry adequate current machines without having insulation breakdown.

Reducing energy loss

Thirty-six (18.1%) food companies were ignorant of the cost of electrical energy inefficient use and wastage to their profitability. They left the situation unchecked.

However, most (55%) of the respondents said the strategies they employed in energy saving did not bring about a reduction in their electricity bills. This was because only three (27.2%) out of eleven strategies were effective in reducing the companies' electricity bill by 3% for the same quantity of production. The three strategies are:

- (1) Switching off most lighting during day time.
- (2) Instant replacement / tensioning of worn out / slack belts or chains.
- (3) Disconnection of all faulty equipment. This finding shows that 72.8% of all the acclaimed strategies to reduce energy consumption were not effective.

Summary and Conclusion

This research work examined the pattern of energy consumption in selected food companies in South-western Nigeria; identified the sources of electrical energy waste and assessed the effectiveness of the strategies for electrical energy savings in the industry. Four sub-sectors of food and drinks industry in the category of Small and Medium Enterprises were examined. They include; beverage, bakery and confectionery, grain mills and storage of cold food products.

The pattern of electrical energy consumption in the food companies was mainly from generating set; this was due to either low voltage or epileptic power supply from national grid. Also, the study identified 12 direct sources that lead to electrical energy waste and inefficient energy utilization in the food industry. One of these, among others was the energy loss as a result of worn out or slack / misaligned belts that needed timely replacement or tensioning. Other indirect sources identified include training and retraining of staff, power factor of electrical equipment, and equipment age, among others.

Moreover, the research also assessed the various strategies and methods, which were practiced by the firms to reduce their electricity bills; as well as improving their machines' efficiency. The corresponding effectiveness of

these strategies was equally looked into.

Eleven strategies were assessed. Three (27.2%) out of the eleven methods had positive effect of reducing the companies' electricity bill by 3% for the same quantity of production. These are:

- (1) Switching off most lighting during day time.
- (2) Instant replacement / tensioning of worn out / slack belts or chains.
- (3) Disconnection of all faulty equipment. This finding shows that 72.8% of all the acclaimed strategies to reduce energy consumption were not effective.

However, the research observed that innovation measured by introduction of modern technology was necessary if the rate at which energy is consumed by food industries in the South-western Nigeria is to be reduced. This finding also suggests the need for Nigerian Industries to develop innovative skill and culture, network with government agencies and non-governmental organization or vice versa and develop alliance amongst them. This would in turn enhance their competence in the area of energy saving in their respective industries; build the global competitiveness of their firms and consequently reduce the green house gasses emissions.

Policy recommendations

(i) Energy audits are almost never done in most developing nations' industries; and being energy conscious could save substantial amount of money and energy. The use of computers in energy analysis and audits is severely limited. Lack of software and trained personnel are responsible for the low influence of computers in tackling energy related problems in the developing nations as it is achieved in the developed ones. Companies could therefore form alliance among themselves to invite energy experts. These will reveal all necessary adjustments that should be made which may lead to energy saving and consequently reduce the energy bills. Therefore, a well performed initial energy audit by policy formulation and implementation committee may be useful in convincing risk adverse management of the potential benefits (financial) that will accrue to the national economy if set goals were achieved. This is similar to what Tony Blair did when he inaugurated the Advisory Group on Energy Management (AGEM) and confirmed the appointment of a full-time energy manager in 1993 to look into how it could reduce its energy consumption (EEMU, 2004).

(ii) It is possible to utilize the heat lost to the outside air through a typical window air-conditioner unit to heat water, thereby providing hot water for domestic use; therefore, food industry in the developing world should find waste heat recovery projects quite attractive.

(iii) Company owners, top management staff and supervi-

sors should take it upon themselves to constantly go round the factory with a view to checking all the avenues whereby energy is being inefficiently utilized either through machines, equipment or workers' negligence of duty. The contributions of company owners in conserving energy are very vital as they could call for shut down to conserve energy and reduce cost of production to enhance profit.

(iv) The success of any energy management program in food companies depends upon imparting proper training to, and securing the cooperation of the human work force in the plant. Workers' attitude should be checked constantly to ensure they discharge their duties promptly and effectively. Also, personnel should be trained to improve their reasoning level and capability. It costs less to do things right the first time; if industries could avoid trial and error procedure, simple things like proper orientation on staff attitude to general energy conservation measures could save considerable energy and money.

(v) Energy waste is attributed to lack of diligence, commitment and readiness of company workers to compliment management efforts in training them. If leaking valves, faulty steam traps, inoperable thermostat controls, lubrication of bearings, motors, conveyor belts, cleaning of lamps' reflecting surfaces, which indirectly result in additional costs could be attended to in time; those additional costs would be eliminated or reduced to the barest minimum.

(vi) When a new plant is to be constructed, care should be taken at the beginning to make it energy-efficient. Motors and lightings, which have high-power factor, should be installed from the inception of the plant. Likewise, power factor improvement measures should be taken early. Again, matching-of-loads to speeds increase motors efficiency. Similarly, companies in the developing countries should be encouraged to invest in modern technologies such as night-setback, and set thermostat controls to shut off lights and boilers when the day's work is over. More energy could be saved, if switching could be done automatically.

Furthermore, the cooling capacity of an air-conditioning plant could be reduced considerably if spray roof cooling system is used in the food industries' architectures. This would replace the more conventional methods of provision of false ceiling, insulation and shading of roof; to reduce the heat flux. Gunnysack has been found to be a good choice for the retention of water on the rooftops.

(vii) Just like the National Agency for Food, Drug Administration and Control, (NAFDAC) empowered to check all food and drug that are imported to the country and even to have a say on what comes to Nigeria from their primary place of production overseas, both governmental and non-governmental engineering bodies/organizations should be empowered alongside with Standard Organization of Nigeria (SON), Council for the Regulation of Engineering in Nigeria (COREN) by the Nigeria government to formulate and implement policies to promote

energy conservation and efficiency in the South-western food industry in particular and Nigerian industries in general. These bodies/organizations could have it in their mission statement to inspect all industrial machines / equipment in terms of their power factor which may be a function of the machines' designed voltage and current as written on the machine's name plate; they should also inspect (at the primary production place) quality and size of cable that are used in winding the electric motors which accompanied these equipment to Nigeria.

Furthermore, standby mode of computer monitors and office televisions should be prohibited.

(viii) Privatization of electrical power generation, transmission and distribution, as it was implemented on Nigerian Telecommunications (NITEL), should be formalized to create competition among the 'would be' power producers and marketers. Also, the use of card-induced metering would be of equal importance in getting value for money. This will enhance regular and normal supply of electricity to our industries, thereby reduces the number of hours that standby generating plants are run. Then the quantity of green house gasses that is released into the atmosphere will reduce.

(ix) The Nigerian government has, no doubt, done excellently well by establishing industrial areas / avenues where some groups of industries are located with a view to having their electricity (11 or 33kV) supplied to them directly. Government needs to (in addition to this) inaugurate some agencies to formulate and implement policy on what electrical appliances, gadgets, equipment / machine, and lighting system among others to be used especially at work to reduce the rate at which energy is consumed in our industries. The policy should disregard the sayings of some companies, who can pay, regardless of their energy bills; rather the policy should focus on the machinery/equipment and man-power on ground as far as power generation is concerned. If energy is inefficiently used either as a result of no relevant or unimplemented policy; and more electrical energy is demanded above what is being generated or above what the national power generation plants can handle; the result will be similar to the situation that is being experienced in the power system today. It will do Nigeria much good, if energy conservation technique can be made compulsory in all its industries.

Suggestions for further studies

The Nigeria government has recognized the economic contribution of the food and beverage industry to economic growth and development. The government had thus given support to the development of food industry in the country through the establishment of relevant agencies. It is considered desirable to examine such support system provided by the States' and Federal Ministry of Industry, Ministry of Agriculture and Natural Resources in

the state level, the National Agency for Food, Drug and Administration Control (NAFDAC), Federal Ministry of Mines and Power, Power Holding Company of Nigeria (PHCN) and Directorate of Food, Road and Rural Infrastructure (DFRRI) in the past. Further study would also be needed to investigate the extent to which food industry are harnessing the support provided by both governmental and non-governmental organizations and how the level of utilization of the support can be enhanced.

REFERENCES

- Adegbulugbe AO (1991). The Energy-Environment Nexus: The role of energy efficiency In: Energy issues in Nigeria: Today and Tomorrow a Conference proceeding of the Nigerian National Committee of the World Energy Council, 22-24 May pp. 59-69.
- Adegbulugbe AO, Oladosu GA (1994). Energy use and CO₂ Emissions in the West and Central African Region pp. 499-508.
- Adolfson MY (1982). Energy Analysis for Energy Conservation in the Food Processing Industry pp. 89-98.
- Aina OO (2002). Analysis of Energy Use Patterns in Nigeria's Industrial Sector: A Case Study of a Cashew-Nut-Processing Plant, Proceedings of the 4th International Conference of the Nigerian Institution of Agricultural Engineers 25: 70-77.
- Akarakiri JB (1990). Wood Energy in Nigeria 16(5): 875-878.
- Akinbami JFK, Ilori MO, Adeniyi AA, Sanni SA (2001). Improving Efficiency of Energy Use in Nigeria's Industrial Sector: A Case Study of a Beverage Plant, Niger. J. Eng. Manag. 2(2): 1-8.
- ANSI/NEMA (2002). Motors and Generator Windings for Efficiency, Publication MG 1-2002 Washington, DC.
- Blair T, Beckett M (2004). Launched Defra's Five year strategy, 8, December.
- EDRC (2002). New Environmentally Sound Energy Strategy for Development of Sub-Saharan Africa. In Karakezi, S and Mackenzie (eds): Energy option for Africa, London: Zed.
- EEMU (2004). How much Energy to process one pound of meat? A comparison of energy intensity in the meat industry of four European countries, submitted to Environmental Science and Policy [2, under review, also M].
- ESMAP (1991). Energy in Food Processing Elsevier, Amsterdam pp. 137-153.
- Elliot LY, Hori TT (2005). Promotion of Energy Conservation in Industry and International Cooperation, International Cooperation Department, Energy Conservation Centre, Japan.
- Energy Book (EB). (2003). Energy Consumption in Grain-Processing Operations in Nigeria: Selected Case Studies, J. Agric. Mechanization in Asia, Africa and Latin America, 13(2): 30-35.
- Energy Institute Press (EIP) (2003). Energy Utilization Pattern in the manufacture of Black Tea, Journal of Agricultural Mechanization In Asia, Africa And Latin America 27(4): 65-70.
- Eyre JT (1998). Promotion of Energy Conservation in Food Industry and International Cooperation, International Cooperation Department, Energy Conservation Centre, Japan.
- Jesuleye OA (1999). Analysis and Policy Implications of Energy Demand in the Nigerian Petroleum Refining Industry. Being a Masters Thesis at Technology Planning Development Unit, Obafemi Awolowo University, Ile-Ife, Nigeria.
- Knutson GD (1981). Industrial Energy Management in Developing Countries pp. 76-79.
- Singh RP (1986). Energy Accounting in Food Process Operations, Food Technol. 32(4): 40-46.
- W.A.P.P (2002). Renewable electricity policy in European Countries, ECN, Report ECN-C-03-071[2, M].Washington, DC.
- Wulfinghoff KT (2003). Potential Benefits from Improving Power factor pp. 109-112.