ASSET Series B (2008) 7 (2):91-103

ASSET
An
International
Journal

ENERGY EFFICIENCY OF A MANUFACTURING INDUSTRY: A CASE STUDY OF NIGERIA EAGLE FLOUR MILLS LIMITED, IBADAN

P.O. AIYEDUN[1], O.A. ADEYEMI[2] AND B.O. BOLAJI[3]

[1, 3]Mechanical Engineering Department, University of Agriculture,
P.M.B. 2240, Abeokuta, Nigeria - e-mail: laiyedun_494@yahoo.com
[2] Mechanical Engineering Department, University of Ibadan, Ibadan, Nigeria

ABSTRACT

The use of energy pervades every aspect of modern society but it is not efficiently used in many industries. In view of the fact that there is an incessant increase in fuel costs, energy efficiency studies are thus rapidly becoming more important. Therefore, this study investigates the energy efficiency in Nigerian Eagle Flour Mills Limited, Ibadan. An analysis/audit is made of energy consumption in the company for a period of five years i.e. 1996 – 2000. The results show that energy is not quite efficiently utilized because the energy productivity increased substantially from 0.369 $MJkg^{-1}$ in 1996 to 0.716 $MJkg^{-1}$ in the year 2000. An average of 47,810.59 GJ of energy is consumed annually within this period with 44.68%, 0.23%, 42.16% and 12.93% of this energy accruing from electricity, lubricants, diesel and petrol, respectively. The average energy productivity, the average intensity of energy and the average cost of energy input per unit kg are 0.527 $MJkg^{-1}$, 1.084 GJm^{-2} and 28 kobo/kg, respectively. The average value of the normalized performance indicator (NPI) obtained is 0.199 GJm^{-2} which indicates substantial energy consumption for the building type.

Keywords: Energy, consumption, productivity, efficiency, manufacturing industry.

INTRODUCTION

In the last decade, there has been a greater awareness of the energy problems facing the world than at any other period in history. It is now widely accepted that the current rate of energy generation and supply can not match the rapid growth in the rate of energy consumption (Adegoke and Bolaji, 1999; Momoh and Soaga, 1999). The importance of energy in sustained economic development is a well-accepted fact. Energy has always been an essential input to all aspects of the modern social life; it is indeed the life-wire in industrial production (Garba, 1999).

Over the centuries, man has used various sources of energy in order to meet the basic essentials of life. Currently, fossil fuels provide the bulk of the world's primary sources of energy, with hydro-electricity providing about 2% and nuclear fission, wood and other sources each accounting for 1% of the primary industrial energy used in the world (Aiyedun and Ologunye,

ISSN 1595—9694 © UNAAB 2003

2001). Since fossil fuels are non-renewable natural resources, their reserve may soon get completely depleted (Garba et al., 1999)

Present energy sources are yielding energy with increasing difficulty. Each unit of energy resource costs more to find, exploit and refine. Energy conservationists are battling offshore exploration efforts, the installation of new pipelines, and construction of refineries and nuclear plants, and these make the job of satisfying our ever-increasing demand for energy more difficult. Hence, energy studies, analysis and audits are done in order to increase efficiency in energy utilization.

Also, the second law of thermodynamics makes it clear that though energy can be converted from one form to another, not all the part of converted energy is available for utilization. That part which is available for utilization is know as available energy or exergy and that part which according to the second law of thermodynamics must be rejected to the heat sink is known as non-available energy or anergy (Eastop and McConkey, 1996).

It is, therefore, obvious that from any energy source, there will definitely be non-available energy and so 100% efficiency is not possible in energy utilization. But a percentage of efficiency is acceptable; and when the percentage is lower than expected, this is considered as wastage of energy. It is to curtail such unnecessary losses that energy efficiency study is highly desirable. Though energy efficiency study is not in itself a solution to the above, but it is an eye opener to the existence of such problem(s) for which solution(s) could be sought.

The need to conserve energy in manufacturing industry is of paramount importance, thus making the cost of energy of immediate interest to Managers and Engineers in this sector. In order to reduce the operating and maintenance costs to a minimum, the cost of energy consumption, which is the prime factor under operating cost, must be closely monitored (Payne, 1997; Smith, 1999). The efficiency of energy utilization in a manufacturing industry required the knowledge of energy performance of machines and plant directly associated with the production process. It is important to account for total consumption, cost and how energy is used for each commodity such as steam, water, air and natural gas. The Energy Manager focuses his professional attention on how to reduce energy consumption per unit of production, i.e., energy efficiency (Albert, 1991; Esan, 1998; Aiyedun and Ologunye, 2001; Aiyedun and Onakoya, 2002).

Several millions of naira can be saved in accumulated energy cost when energy is properly managed. Energy programs are relatively new for most companies in developing countries as survey shows that most companies in these countries do not have energy programs. However, the results of a study carried out in the United States from 1971 to 1986 show a reasonable accumulated reduction in energy consumption through implementation of energy management programs (Maurice and Wilson, 1998). To ensure the best possible savings, good audit and survey must be carried out. An energy audit is an essential activity for any organization wishing to control energy and utility costs.

The whole purpose of energy efficiency is to minimize the amount of energy used to get a desired effect. There are various principles that can be followed in energy management whose focus is the reduction of energy productivity and they include; historical energy use review, energy audits (review of current practices), thorough analysis of energy use (engineering analysis, computer simulation, availability studies, e.t.c.), aggregation of energy uses, energy conservation to mention but a few (Eastop and Croft, 1990; Payne, 1997). The objective of this study, therefore, is to analyse the energy consumption, productivity and efficiency of a private sector in order to identify where the industry uses and wastes energy, and where actions for energy conservation can be implemented.

METHODOLOGY

Numerical Data Collection and Analysis

The surveying of specific systems and equipment in the industry picked was used as a case study and then through the compilation of already available data, net energy charged to main product and energy credit for by-products are deduced. The prime source of data for analysis of the performance of industrial operation as they exist in practice is the individual plant operator.

Description of the system

The floor area of the factory is 44100 m^2. The major sources of energy are electricity from PHCN and also through generating plants. There are 2 mills in the milling house; one is the wheat mill, while the other is the maize mill. The capacity of the wheat mill is 500 tonnes per 24 hours but the mill is only used for about 15 hours per day while the capacity of the maize mill is 170 tonnes per 24 hours but only used for 8 hours per day.

The system input materials are wheat and maize grains while the output materials are wheat flour, wheat bran, semolina, cake flour, maize grits. The operations included in the system are energy associated with fuels and lubricants and energy used for all administrative and other non-production functions (Smith, 1998).

The data collected include:

- Electricity, diesel fuel, lubricants and petrol consumed from 1996 – 2000
- Production for this same period. These data are recorded in tabular form as shown in Tables (1 – 5)

Total energy consumed

Total energy consumed is the summation of the amount of electricity, lubricants, diesel and fuel used after conversion to energy (Appendix A) and is shown in Table 6.

Intensity of energy

This is defined as the ratio of annual energy consumed in GJ to the factory floor area in m^2, i.e.,

$$intensity\ of\ energy\ (GJ/m^2) = \frac{total\ energy\ consumed\ (GJ)}{floor\ area\ (m^2)} \qquad (1)$$

This was calculated for a period of 5 years (1996 – 2000) and the result is graphically illustrated in Fig. 1. The intensity of energy for this period varies between 0.78 GJm^{-2} and 1.32 GJm^{-2} with an average of 1.08 GJm^{-2}.

Energy productivity

This is the total energy consumed per unit production, i.e.,

$$energy \quad productivity = \frac{total \quad energy \quad consumed \quad (MJ)}{total \ \text{production} \quad (kg)} \qquad (2)$$

This was calculated for the same years and the result is graphically illustrated in Fig. 2. The average energy productivity obtained was 0.527 $MJkg^{-1}$.

Table 1: Monthly energy consumption and production output for 1996

Month	Energy Source				Total (GJ)	Total (N)	Total Production (Tonnes)
	Electricity (GJ)	Diesel (GJ)	Petrol (GJ)	Lubricant (GJ)			
January		4680.83	60.54		4741.37	1,135,716	6715.53
February	796.68	1422.50	349.95	24.59	2593.72	1,065,938	5037.79
March	1321.20	1620.89	38.17	8.28	3336.46	1,403,733	7603.67
April	1978.20	2014.96	225.53	16.39	4235.08	1,893,572	6630.07
May	1968.84	636.13	311.25		2916.22	1,543,157	7623.41
June	1854.00	693.41	75.54	80.20	2631.15	1,421,532	5657.53
July	1586.52	929.02	72.55		2588.09	1,288,370	5856.81
August	1435.68	699.33	73.13	16.39	2224.53	1,215,411.5	6686.35
September	1464.48	396.14	62.88		1923.50	1,150,249	4927.30
October	1428.12	190.25	80.46		1698.83	1,010,191	5330.29
November	1428.12	1099.89	40.50		2633.31	1,1257,728	6492.57
December	1774.08	674.56	42.95	8.20	2499.74	1,363,323.5	4813.76
Total	17100.72	15057.9	1781.45	81.97	34022.04	15,635,111	92172.48

Table 2: Monthly energy consumption and production output for 1997

Month	Energy Source				Total (GJ)	Total (N)	Total Production (Tonnes)
	Electricity (GJ)	Diesel (GJ)	Petrol (GJ)	Lubricant (GJ)			
January	1518.12	1195.90	63.24		2777.26	1,304,184	5968.08
February	1507.68	1257.63	403.66		3168.97	1,445,,941.75	5879.26
March	1238.76	955.08	941.23		3135.07	1,390,797	8066.53
April	1600.56	1239.08	8O3.79		3643.43	1,595,230	8846.77
May	1777.68	1019.64	805.06		3602.38	1,672,227	7990.62
June	1533.60	1677.45	589.44	24.59	3825.08	1,662,584.22	7428.32
July	1138.68	1540.00	661.78		3555.87	1,438,414	7401.28
August	1274.04	960.81	661.78		2896.63	1,270,432	8532.36
September	1665.36	846.33	118.05		2629.74	1,334,451	8308.85
October	1906.56	1160.22	776.12		3842.90	1,769,336	8134.24
November	1635.84	1213.36	699.11	8.20	3556.51	1,580,308	8808.71
December	1729.44	1220.94	532.61	8.20	3491.19	1,621,818	8552.66
Total	18526.32	14286.43	7254.61	57.38	40141.12	18,079,772.97	94017.46

Table 3: Monthly energy consumption and production output for 1998

Month	Energy Source				Total (GJ)	Total (N)	Total Production (Tonnes)
	Electricity (GJ)	Diesel (GJ)	Petrol (GJ)	Lubricant (GJ)			
January	2014.56	647.41	485.13		3147.1	1,922,184	8139.32
February	1697.76	1395.84	933.06		40707.68	2,637,258	10164.94
March	1397.52	2787.64	1331.29		5516.45	3,064,791	8002.86
April	1274.76	2122.28	1310.64		4707.68	2,637,258	10164.94
May	2452.32	2674.88	1152.87		6280.07	3,603,191	101744.31
June	1843.20	2304.04	1255.93	24.59	5427.76	3,207,741	12437.2
July	2516.40	3413.06	1137.80	16.39	7067.26	3,435,162.75	12414.65
August	2414.88	2859.66	1371.80		6646.34	3,793,263	12538.7
September	1810.80	1905.41	949.72		4665.93	2,679,202	10039.09
October	2201.76	1459.87	2208.99		5870.62	2,954,635	9819.88
November	1881.00	1235.76	969.79	8.20	4094.75	2,119,116.50	8408.48
December	1438.92	3705.16	689.29	8.20	5841.57	1,650,942	11077.15
Total	22943.88	26511.00	13796.11	57.38	63308.37	36,408,939.25	122775.87

Table 4: Monthly energy consumption and production output for 1999

Month	Energy Source				Total (GJ)	Total (N)	Total Production (Tonnes)
	Electricity (GJ)	Diesel (GJ)	Petrol (GJ)	Lubricant (GJ)			
January	2616.48	1970.35	802.13		5388.96	3,161,266	10275.92
February	1985.76	2378.14	836.84	16.39	5217.13	3,012,198	8064.08
March	1479.6	4196.71	910.55	8.20	6586.42	3,619,078	9934.17
April	1661.40	2293.86	773.36	24.59	4753.21	2,780,621	10228.07
May	2168.64	1263.40	518.58		3950.62	2,352,04	3055.8s
June	1408.32	1658.01	114.71	8.20	3189.30	1,856,085	1189.37
July	1555.56	896.55	55.93		2508.04	1,506,902	1054.74
August	1505.16	1044.72	32.37	8.20	2590.45	1,549,633.22	684.61
September	1304.28	547.59	62.37	32.78	1946.99	1,304,020	7621.37
October	1426.68	529.75	62.34		2049.09	1,257,663	6147.4
November	1569.60	718.53	92.66		2406.87	1,461,366	6582.27
December	1372.68	1311.21	138.30	8.20	2830.39	1,670,980	6962.27
Total	20054.52	18808.88	4447.51	106.56	43417.47	25,532,40732	71805.53

Table 5: Monthly energy consumption and production output for 2000

Month	Energy Source				Total (GJ)	Total (N)	Total Production (Tonnes)
	Electricity (GJ)	Diesel (GJ)	Petrol (GJ)	Lubricant (GJ)			
January	1569.60	212.43	92.73		3786.76	2,273,092	6122.23
February	1504.08	1355.60	125.97	32.78	3018.43	2,015,240.5	6607.80
March	1456.20	2194.01	347.33	16.39	4013.93	2,452,401	7736.04
April	1272.24	2316.60	515.20		4104.04	2,442,736	7021.23
May	1116.00	1330.37	390.50	8.20	2845.13	1,742,173	8105.95
June	1134.00	2837.38	551.85	24.59	4547.82	2,693,905	6758.26
July	936.00	2957.33	267.80	8.20	4169.33	2,456,666.75	7281.2
August	1094.26	2181.67	208.63		3484.56	1,374,361.2	8306.33
September	1914.05	2688.27	432.97		5035.29	3,021,943.6	6307.04
October	1345.82	1791.45	844.72	24.59	4006.58	2,482,045.02	6268.97
November	1507.82	3323.61	829.72	57.37	5718.52	3,586,915.8	5496.89
December	1229.76	1483.36	802.17	57.37	3572.66	2,417,779	5268.38
Total	25929.43	26595.39	5409.64	229.49	58163.95	29,771,633.87	81280.29

Table 6: Summary of total energy consumed

Energy Source	Energy Consumed (GJ)					Total (GJ)
	1996	1997	1998	1999	2000	
Electricity	17100.72	18526.32	22943.88	20054.52	25929.43	104554.87
Lubricants	81.92	73.76	57.38	106.56	229.49	549.16
Diesel	15057.90	14286.43	26511.00	18808.88	26595.39	101259.6
Petrol	1781.45	7254.61	13796.11	4447.51	5409.64	32689.32
Total	34022.04	40141.12	63308.37	43417.47	58163.95	239052.95

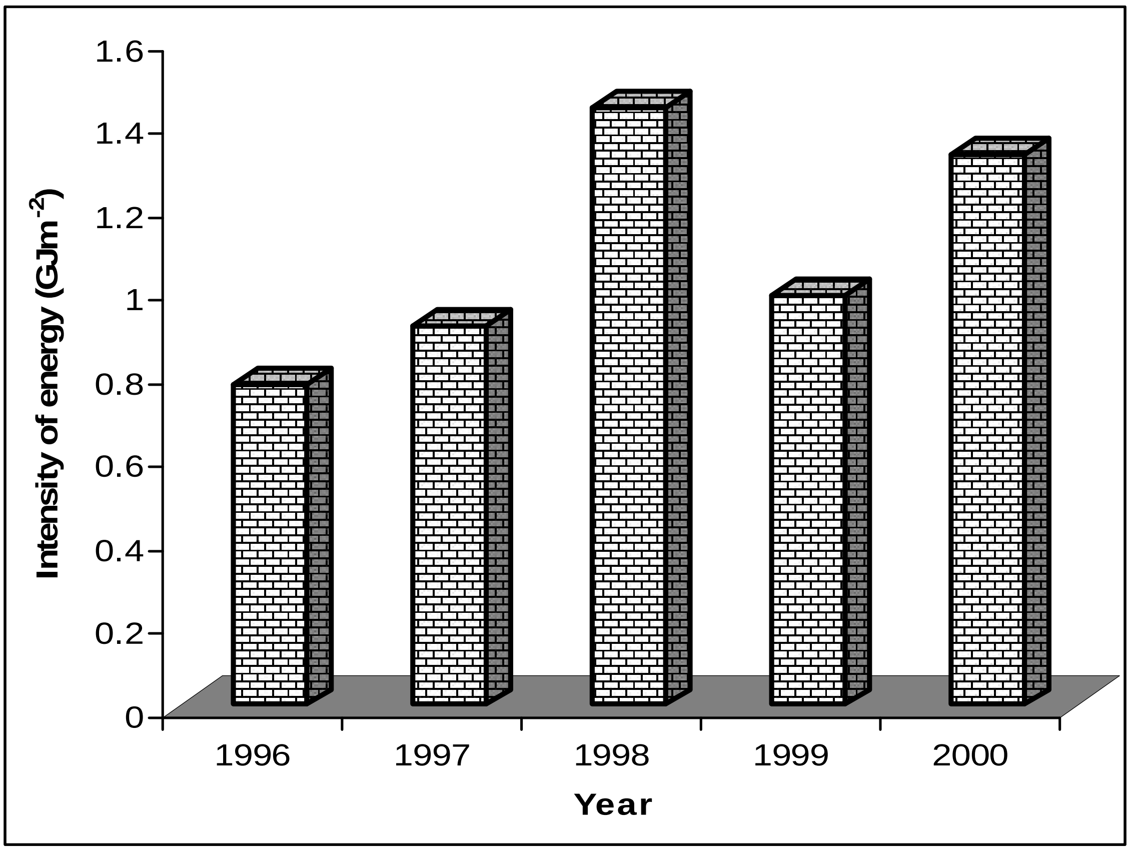

Fig. 1: Intensity of energy for period of 5 years (1996 – 2000)

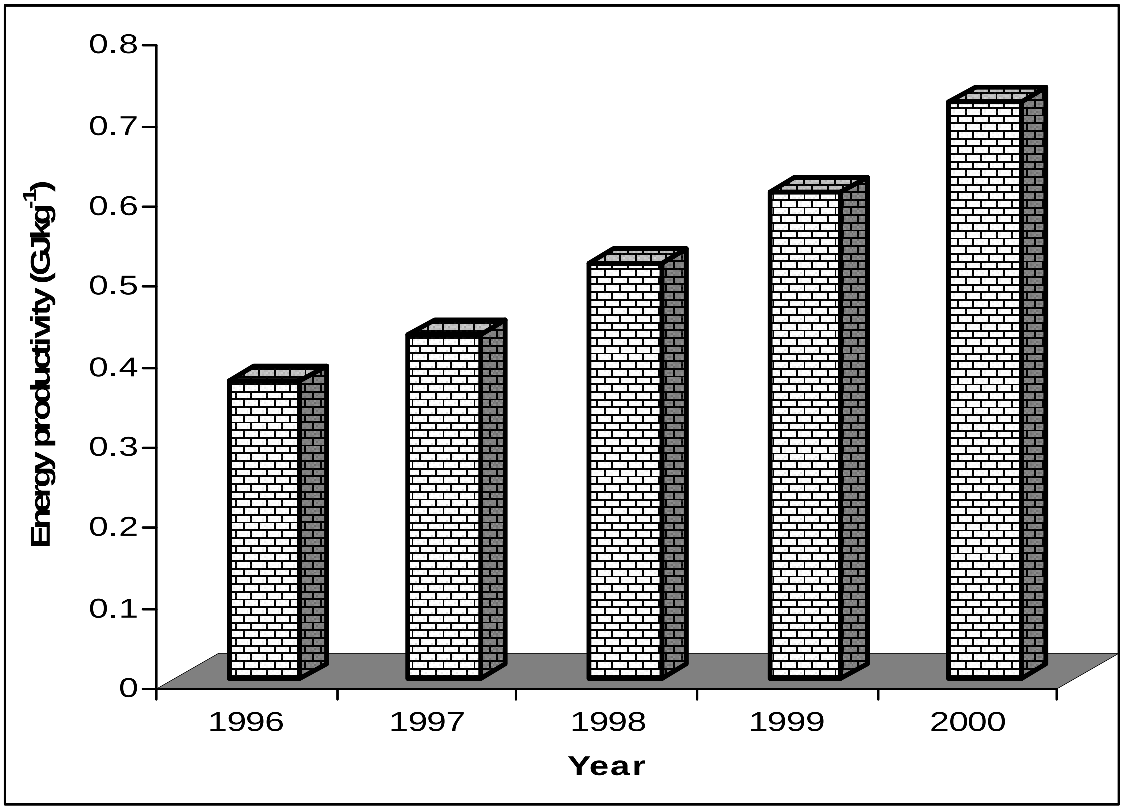

Fig. 2: Energy productivity for period of 5 years (1996 – 2000)

Cost of energy input into a unit product

This is represented mathematically as:

$$\frac{total\ energy\ cost \times energy\ \ productivity}{total\ \ production} \qquad (3)$$

The total energy cost is calculated for the different energy sources based on their respective rates and summed up. Values of cost of energy input for the five years (1996 – 2000) are given in Fig. 3. The average cost of energy input per product obtained was 28 kobo/kg. A steady increase is observed between 1996 and 1999 and tapers off in 2000.

Normalized performance indicator (NPI)

The normalized performance indicator (NPI) is a useful parameter in assessing the energy performance of a building. It is the total energy consumed divided by total floor area and multiplied by the hours of use factor value. The value obtained was compared to the standard NPI value quoted by the Energy Efficiency Office (EEO) for such factory. A building with good rating will require further investigation unless there are no obvious areas of improvement. Favorable rated buildings may deteriorate or the general standard may increase from time to time such that constant monitoring is required by the energy engineer in order to maintain good standard for the building at all times (Fuel Efficiency Booklet, 1993).

$$NPI = \frac{Total\ energy\ consumed \times Hours\ of\ use\ factor}{Floor\ area} \qquad (4)$$

NPI values calculated are given in Fig. 4 and the average normalized performance indicator (NPI) obtained is 0.199 GJ/m^2 which is rated good.

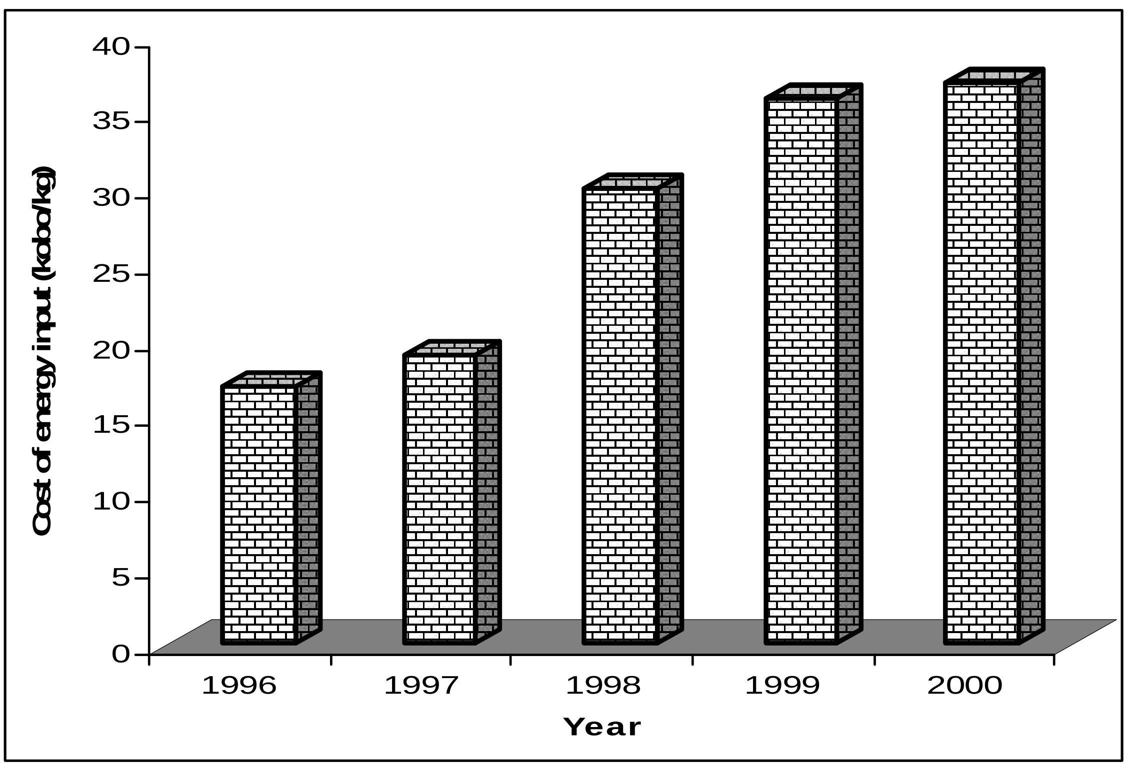

Fig. 3: Cost of energy input for period of 5 years (1996 – 2000)

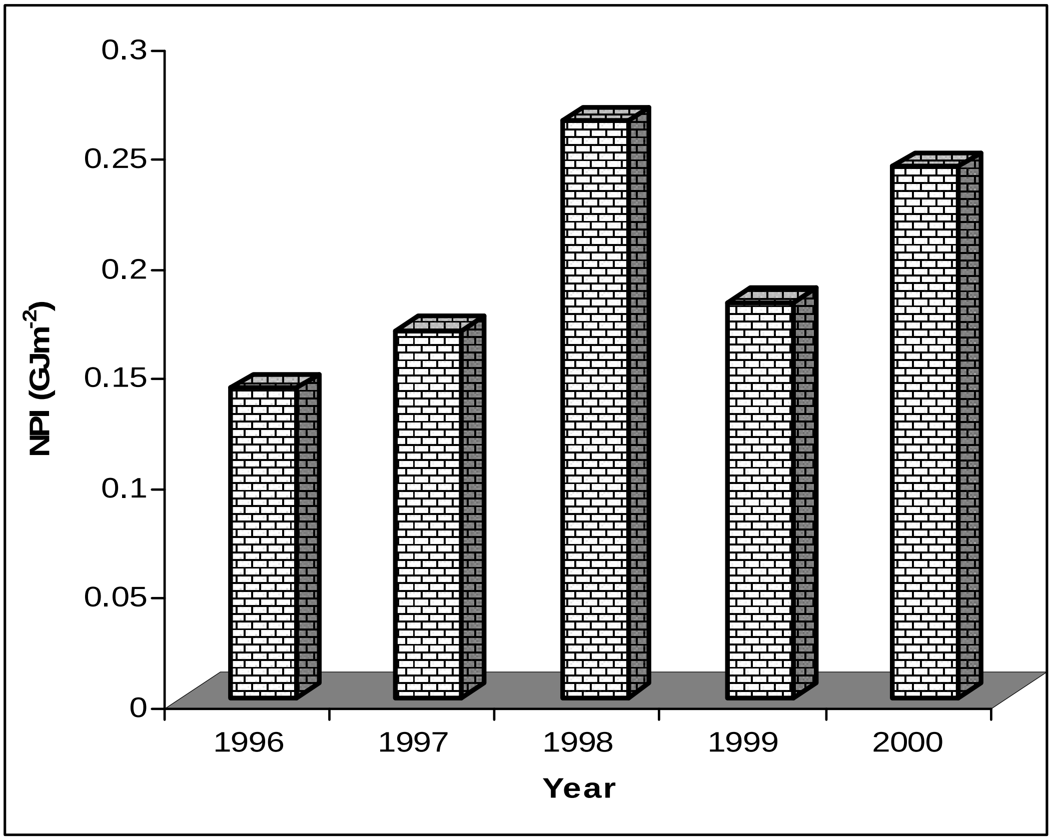

Fig. 4: Normalized performance indicator (NPI) for period of 5 years (1996 – 2000)

RESULTS AND DISCUSSION

The analysis made was based on the data collected from the company. The year 1998 recorded the highest energy consumption of 63,308.37 GJ and it also recorded the highest production of 122775.87 tonnes while 1996 recorded the least energy consumption of 34,022.04 GJ, though it did not have the least production. Rather, 1999 recorded the least production of 71805.53 tonnes.

The summary of the total energy consumed is given in Table 6 having an average annual energy consumption of 239052.95 GJ where electricity, lubricants, diesel and petrol had 44.68, 0.23, 42.16 and 12.93% of the total energy, respectively (Table 7). The average annual production obtained was 92410.33 tonnes. The intensity of energy used varied over the years ranging from 0.777GJ/m^2 in 1996 to 1.319 GJ/m^2 in the year 2000 having the highest value of 1.436 GJ/m^2 in 1998 and an average intensity of 1.084 GJ/m^2.

The average cost of energy per unit product was found to increase yearly being 37 kobo as at year 2000 and having an average value of 28 kobo/kg while the energy productivity was 0.369 MJ/kg in 1996 but a very high 0.716MJ/kg in 2000 having an average value of 0.527 MJ/kg . The average annual cost of energy obtained was N 25,067,572.88k. An average yearly savings of about N 1,750,000 can be obtained when the machines and equipment are properly maintained. This was deduced from the fact that about 7 – 10% of total energy consumed can be saved when proper energy management is followed. Effective maintenance will not only improve the efficiency of equipment and system but it will also prolong their life span.

Table 7: Summary of the percentage of total energy consumed

Energy Source	Total Energy Consumed (%)					Average (1996 – 2000)
	1996	1997	1998	1999	2000	
Electricity	50.26	46.15	36.24	46.19	44.58	44.68
Lubricants	0.24	0.19	0.09	0.25	0.40	0.23
Diesel	44.26	35.59	41.88	43.32	45.72	42.16
Petrol	5.24	18.07	21.79	10.24	9.30	12.93

CONCLUSION

The investigation of the energy efficiency of a manufacturing industry with Nigerian Eagle Flour Mills Limited, Ibadan as a case study is reported in this paper. The paper which is limited based on the available years of data collected (1996 – 2000) analyzed the energy consumption, productivity and efficiency of the company. The areas where the industry uses and wastes energy, and where actions for energy conservation can be implemented have been identified. The results of the analysis made over the five years a period for a treated floor area of 44100 m^2 show that energy was not efficiently utilized. The energy productivity increased substantially from 0.369 $MJkg^{-1}$ in 1996 to 0.716 $MJkg^{-1}$ in the year 2000. An average of 47,810.59 GJ of energy was consumed annually within this period. The average energy productivity, the average intensity of energy and the average cost of energy input per unit kilogram are 0.527 $MJkg^{-1}$, 1.084 GJm^{-2} and 28 kobo/kg, respectively. The average value of the normalized performance indicator (NPI) obtained is 0.199 GJm^{-2} which indicates substantial energy consumption for the building type.

In order to curtail unnecessary wastage of energy and to reduce cost of energy consumption, the following factors must be critically looked into:

- Procurement of test equipment for energy monitoring in the factory.
- Significant capital investment to improve the energy consumption
- Detailed audit to identify the causes of energy wastes.

- Proper maintenance and control must be done in order to improve the energy productivity.

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Appendix A: Typical values for the total energy associated with fuels

Fuel	Quantity	Production and Delivery Energy (MJ)	Energy Content Fuel (MJ)	Total Energy (MJ)	Energy Production Efficiency (%)
Coal	1 kg	1.39	28.01	29.40	95.0
Coke	1 kg	3.93	25.42	29.50	86.6
Electricity	1 kWh	11.40	3.6 *	15.00	24.0
Natural gas	1 therm	15.06	105.44	120.50	87.5
Heavy	1 kg	8.89	42.60	51.49	82.7
fuel oil	1 litre	8.57	40.98 *	49.55	82.7
Kerosene	1 kg	8.89	46.53	55.42	84.0
	1 litre	6.96	36.53	43.4	84.0
Diesel	1 kg	8.89	44.87	53.73	83.5
	1 litre	7.45	37.71 *	45.16	83.5
Petrol	1 litre	6.85	35.97 *	42.82	84.0

Source: Fuel Efficiency Booklet, 1993.

** Values used for computation in the analysis*