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INVESTIGATION OF ENERGY-EXERGY UTILIZATION IN A SUGAR PROCESSING PLANT IN LAGOS, SOUTH-WEST NIGERIA

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ABSTRACT

This research work was designed to study energy requirement and exergy inefficiencies for refining raw sugar in a Sugar refinery plant, Lagos, Nigeria. The study was carried out using a three phases, ten steps energy audit model by Cape and Kennedy (1997). In *this research sugar refining was classified into six unit operations namely: reception and storage, melting, clarification, crystallization, centrifuging, drying/packaging and utility unit operations respectively. The energy intensity for refining 1800 tons of raw sugar input to 1694 tons output was estimated as 420.49 MJ/tons consisting of electrical (65.42%), thermal (34.49%) and manual (0.09%) of the total energy. The most energy intensive section was the utility section with a value of 410,964.27 MJ, while the crystallization group operation was the most energy intensive group in the sugar refining process with a magnitude of 142,720.76 MJ. The exergy analysis revealed that the utility section was responsible for most of the inefficiency (55.45%) followed by the crystallization group operation (18.2%) while the reception and storage, clarification and drying/packaging group operations had 1.27, 2.78 and 3.74%, respectively making them the groups with very little inefficiency. The most exergy loss took place in the boiler house, which accounted for 33.44% of the overall system inefficiency.*

1. INTRODUCTION

Sugar beet was first identified as a source of sugar in 1747. No doubt the vested interests in the cane sugar plantations made sure that it stayed as no more than a curiosity, a situation that prevailed until the Napoleonic wars at the start of the 19th century when Britain blockaded sugar imports to continental Europe. By 1880 sugar beet had replaced sugar cane as the main source of sugar on continental Europe. Those same vested interests probably delayed the introduction of beet sugar to England until the First World War when Britain's sugar imports were threatened. Today, sugarcane is grown in over 110 countries. In 2009, an estimated 1,683 million metric tons were produced worldwide which amounts to 22.4% of the total world agricultural production by weight. About 50% of production occurs in Brazil and India.

The erratic power supply accompanied with increase in electricity tariff have caused a lot of manufacturing industries to rely solely on heavy duty generator and boiler resulting to increase of prices of goods manufactured in Nigeria and this has continued to have negative effect on the industrial sector of Nigeria economy. This aforementioned poor state of electricity supply in Nigeria has imposed significant costs on the manufacturing sector. The bulk of these costs relate to the firms' acquisition of very expensive power backups to cushion them against the huge losses arising from frequent and long power fluctuations which may affect some of their equipment and machines that are sensitive to power fluctuations and outages. Small-scale operators are more heavily affected by the power outage as they are unable to finance the cost of backup power necessary to mitigate the impact of frequent outages. The small-scale operators that could afford to back up their operations have to spend a significant proportion of their investment outlay on this. Consequently, this has made a lot of companies and manufacturing sector to close up and go to other neighboring West African countries in order to have their products compete favorably with similar products manufactured in other countries of the region.

Energy is the ability to do work or to produce heat as an input for various industrial processes (Choat, 2003). In thermodynamics analysis; energy can be converted from one form to another. The structure of thermodynamics involves the concept of equilibrium states. It is postulated that any change in the value of thermodynamic quantities such as, internal energy between two equilibrium states of a system is independent of the thermodynamic path it takes to get from one state to the other. Therefore, it is found that internal energy of a system can be determined by the parameters such as pressure, temperature, magnetic field, surface area, mass, etc, that specify the system in its final and initial states. It means that if a system changes from state 1 to state 2, the change in the internal energy ΔU is (U_2 -U_1). It is important to note that U_2 is less than U_1 i.e. the internal energy in the final state is less than that of the initial state. This difference is independent on how the process reaches state 2 from state 1. Consequently, the internal energy is also known as state function or a plant function that is, functions of the state of the system only and not its history. The thermal energy of a system is the internal energy which can be increased by increasing the temperature. (Ibrahim and Rosen, 2007).

Exergy is defined as the maximum amount of work which can be produced by a system or a flow of matter or energy as it comes to equilibrium with a reference environment. Unlike energy, exergy is not subject to a conservation law (except for ideal, or reversible, processes). Rather, exergy is consumed or destroyed, due to irreversibilities in any real process. The exergy consumption during a process is proportional to the entropy created due to irreversibilities associated with the process. Exergy analysis is a method that uses the conservation of mass and conservation of energy principles together with the second law of thermodynamics for the analysis, design and improvement of energy and other systems. The exergy method is a useful tool for furthering the goal of more efficient energy-resource use, for it enables the locations, types, and true magnitudes of wastes and losses to be determined. In general, more meaningful efficiencies are evaluated with exergy analysis rather than energy analysis, since exergy efficiencies are always a measure of the approach to the ideal. Therefore, exergy analysis can reveal whether or not and by how much it is possible to design more efficient energy systems by reducing the inefficiencies in existing systems.

It is believed that cane sugar was first used by people in Polynesia from where it spread to India. In 510 BC the Emperor Darius of what was then Persia invaded India where he found "the reed which gives honey without bees". The secret of cane sugar, as with many other of man's discoveries, was kept a closely guarded secret whilst the finished product was exported for a rich profit.

2. Necessity of Energy Audit in Sugar Refinery in Nigeria

Energy Minimization/Management is necessarily required because it influences a number of aspects of operation and activities of the Sugar production in the following areas:

i. To check the high costs of energy in Sugar production and manufacturing in south-west of Nigeria.
ii. To enhance the competitive position of the company/plant among its competitors globally.
iii. To prevent energy losses and ensure reduction in energy related wastages in Sugar production in south-west of Nigeria.
iv. To improve Productivity and increase energy optimization in sugar production process in south-west of Nigeria.
v. To enhance the quality and quantity of energy supply within the sugar refinery plant.

3. Research Questions

i. Do we have any energy policy in Sugar production in south-west of Nigeria?
ii. Do we have any energy committee/commission regulation energy utilization in sugar processing in Nigeria?
iii. Are there wastages in energy utilization in sugar processing in Nigeria?
iv. Are there means of measuring energy consumption in sugar processing in Nigeria?
v. Has the sugar refinery plant ever conducted an energy audit?
vi. Is the quality and quantity of energy supply within the sugar refinery plant satisfactory?

4. Objectives of the Study

The main objective of this study is energy audit of Energy and exergy analysis of sugar refinery plant. The specific objectives include:

i. Establishment of energy data base for the sugar refinery plant located in Lagos, south-West of Nigeria.

ii. Identification and scaling the effective cost saving/energy management measures in sugar refinery plant.

iii. Identification of sugar refinery plant energy consumption pattern and factors that have effects on its profitably and general economy.

iv. Determination of economic viability of major energy projects in a sugar refinery plant located in Lagos, Nigeria.

5. Materials and Method

The energy study of sugar refining plant was carried out using a three phase, ten steps audit process model by Cape and Kennedy (1997). The audit reviews energy generation, procurement and consumption pattern in the plant for a period of five years covering January 2012 to December 2016. Data was collected from each of the energy sources and were used to calculate parameters that will enable the researcher compare the efficiencies of all the energy sources. Phase 1 is the pre audit phase, phase 2 is the audit phase and phase 3 is the post audit phase. These steps are explained in details below and the entire research methodology using a process flow chart in figure 1.

Phase 1 (Pre Audit)

Step 1. The method used by Ohwofadjeke and Adigo (2016) was applied here. Prior to the energy audit of the plant, a pre audit meeting was held between; the researcher and members of staff of power/energy unit of the company in order to build co-operation and understanding among all parties. This was to ensure the success of this research work, facilitate acceptability of findings and implementation of recommendations. At this stage plans were made and resources were also allocated to service the material needs of the research work accordingly.

Step 2. At this stage; a walk through audit was carried out by physically visiting all the power stations for inspection, in order to obtain first-hand information on the company energy systems.

Phase 2 (audit phase)

Step 3. At this stage routine visits were made to major energy producing and consuming facilities of the company during which energy bills were sought which are given in Tables 4.1 to 4.5. and plotted in figures 4.1 to 4.5. Also Direct measurement of energy related parameters using; Portable test equipment such as; flow meter, infrared thermometer and Digital clamp multi-meter meter on regular time intervals which are the primary data used for this research work. The works and power department officials were asked Oral questions during each visit; where necessary in order to get the required information on Annual Energy Bills and energy consumption pattern that were used for this study.

Step 4. At this stage detailed survey was carried out on motors, pumps, compressors, lightings, refrigeration and air-conditioning the different units to obtain accurate information.

Step 5. This step assessed daily fuel consumption rate of the power generators in relation to load variation and thermal efficiency.

Step 6. This stage undertook a thorough evaluation of energy use in order to determine energy/material balance and energy losses/waste within the company's energy related facilities.

Step 7. An investigation was made to ascertain whether or not there had been an energy audit and review of energy conservation opportunities in the company in the past.

Step 8. This stage subjected; the energy systems retrofitting analaysis to see areas of possible retrofitting or redesign to conserve energy. Also data collected for the study were analyzed using appropriate formalea and techniques.

Step 9. This stage involved the preparation of final energy report, presentation of seminars and final defense of this thesis.

Phase 3 (Post Audit phase)

Step 10. This final stage that involved; submission of final audit report, the implementation of recommendations and follow up procedure.

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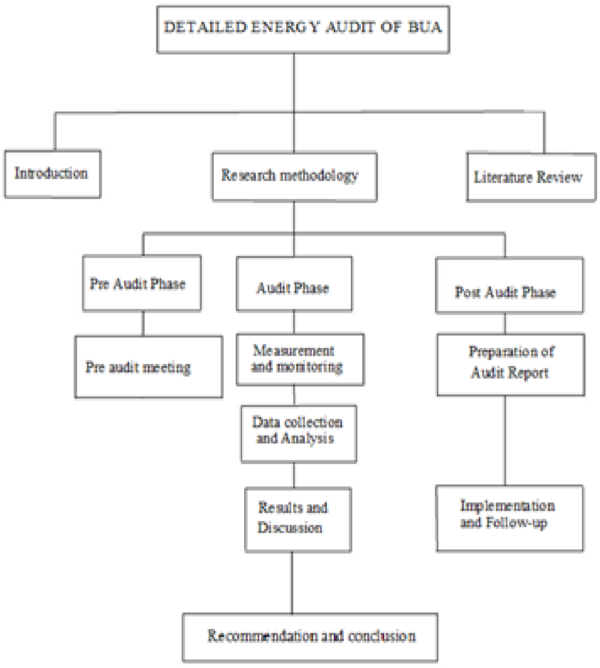

Figure 1 Process Flow Chart of Energy study of Sugar refining

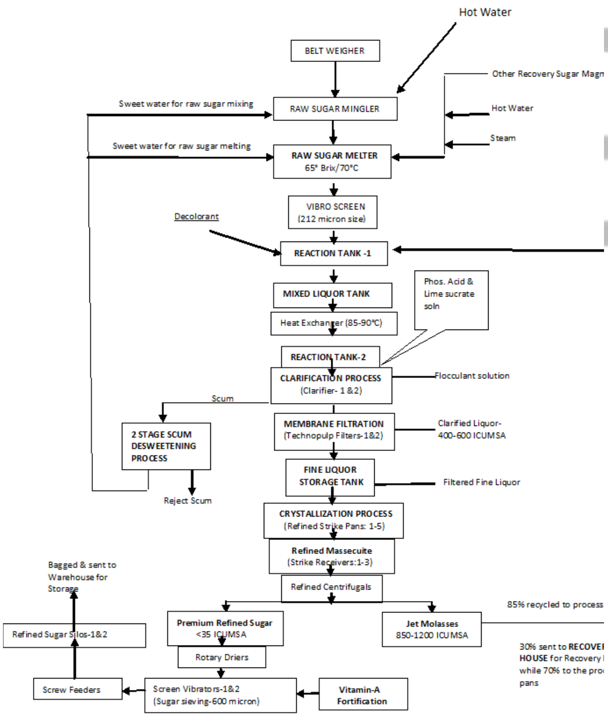

Figure. 2 sugar Refining Process flow chart

6. Data Collection

The data for this study were obtained through various means; the primary source of data was obtained through direct measurements of energy related parameters within the plant. While, the secondary source of data was through; the plant's electricity/fuel/energy source procurement, generation and consumption data from January 2012 to December 2016 which were collected from the Power & Energy unit of the company and analyzed. Also Oral/personal interview of Energy Managers in the power section of the company was conducted so as to gather all required information for this study.

The following data were collected:

- ✓ Electricity, diesel, LPFO and natural gas consumed per month over a 5 years period;
- ✓ Production rate of the Company per month over a 5 years period;
- ✓ Number of working hour per day;
- ✓ Number of occupancy (shift) per day;
- ✓ Floor area of the factory;
- ✓ Power rating of all machines/equipment powered by electricity.

7. Method of Data Analysis

The data were analyzed using Calculations involving:

- ✓ Total fuel consumption per year
- ✓ Fuel specific exergy.
- ✓ Annual Energy consumption in kWh
- ✓ Energy efficiency performance
- ✓ Comparison of different energy efficiencies
- ✓ Summary of total energy consumed
- ✓ Summary of percentage Energy consumption
- ✓ Yearly Energy cost
- ✓ Summary of Percentage Energy Cost
- ✓ Normalized Performance Indicator (NPI)
- ✓ Evaluation of Energy Productivity
- ✓ Evaluation of Energy Intensity
- ✓ Evaluation of thermal Energy
- ✓ Evaluation of Manual Energy
- ✓ Evaluation of Electrical Energy

- ✓ Estimation the Energy Input into Each Unit Operation
- ✓ Total Energy Input into the Entire Refining Process

8. Results and Discussion

The primary data used for this analysis were obtained from direct measurements of energy and exergy related parameters, while the secondary data were collected from the company energy manager. The results are as follows;

Table 1. Energy consumption and production output (2012)

Period MONTH	ELECTRICITY (NEPA) (kwh)	ELECTRICITY (NEPA) (GJ)	GEN. SET FUEL(DIESEL) vol. (ltr)	GEN. SET (GJ)	BOILER (LPFO) vol. (ltr)	BOILER (LPFO/Gas) (GJ)	PRODUCTION Metric Ton
JAN	86.93	312.948	20.92	847	192.05	7854.85	157.693
FEB	83.69	301.284	37.52	1.52	270.321	11056.1	164.496
MAR	91.92	330.912	23.012	932	249.52	10205.4	175.983
APR	88.69	319.284	31.205	1.264	189.206	738.525	140.114
MAY	89.12	320.832	28.084	1.137	215.221	8802.54	180.391
JUN	87.69	315.684	35.665	1.444	188.765	7720.49	170.281
JUL	91.26	328.536	20.803	843	179.51	7341.96	152.228
AUG	71.52	257.472	53.337	2.16	271.02	11084.7	165.396
SEP	75.265	270.954	60.611	2.455	257.15	10517.4	160.754
OCT	76.03	273.708	51.123	2.07	290.21	11869.6	146.162
NOV	108.54	390.744	48.564	1.967	263.821	10790.3	180.379
DEC	74.54	268.344	32.76	1.327	261.59	10699	175.211
TOTAL	1025.2	3690.7	443.604	17.966	2828.38	115681	1969.09

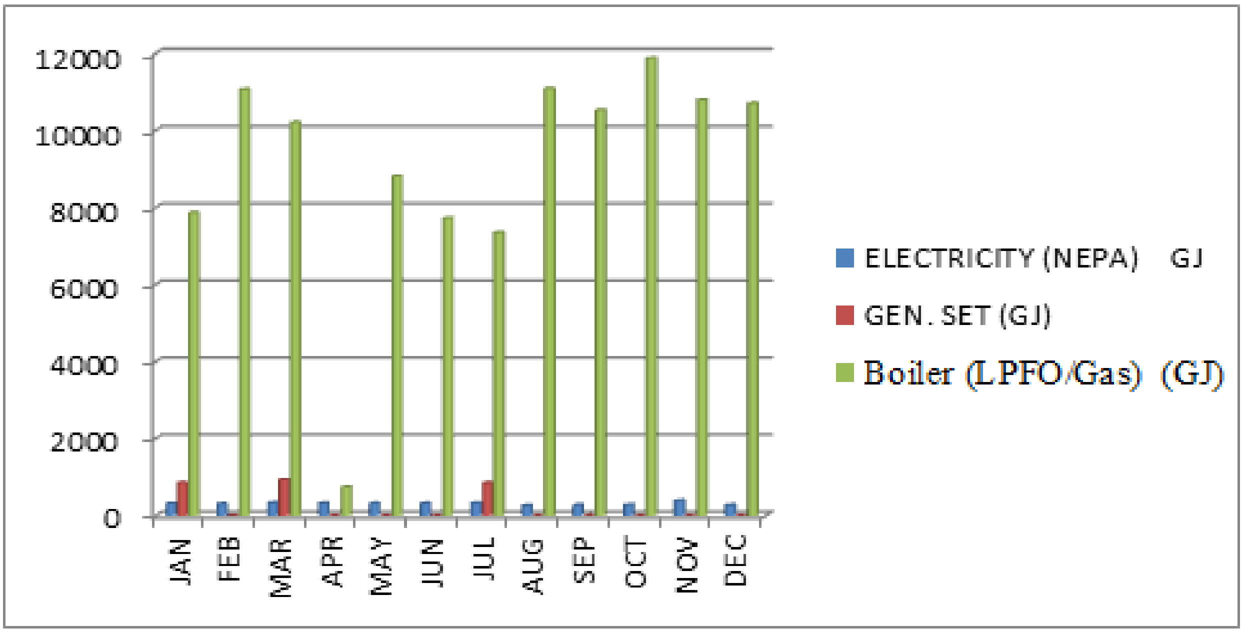

Figure 3. Energy consumption and production output (2012)

Table .1 and figure 3 respectively show that in 2012, Boiler (LPFO/natural Gas) supplied 97 % of total energy consumed by the plant. PHCN supplied 3.09 % of total energy while diesel driven Generator supplied 0.015 % of the total energy. It can be seen that diesel driven Generator had made least contribution which perhaps might be due to the high cost of diesel when compared with that of PHCN supply and LPFO/gas powered boilers in Nigeria market. The unavailability of electricity supply from national grid posses a lot of problem to the manufacturing industries operating in Nigeria, thus increases the cost of production which makes the final product expensive and almost beyond the reach of a larger percentage of the populace who are usually low income earners. This in turn results in low demand and subsequent low profits for investors of such facilities. In the recent time, due to unavailability of electricity supply companies like Michelin and Dunlop just to mention but a few have relocated their production plants from Nigeria with the consequence of job losses for Nigerians and loss of Tariffs for the government.

Table .2. Energy consumption and production output (2013)

Period MONTH	ELECTRICITY (NEPA) (kwh)	ELECTRICITY (NEPA) (GJ)	GEN. SET FUEL(DIESEL) vol. (ltr)	GEN. SET(GJ)	BOILER (LPFO/Gas) vol. (ltr)	BOILER(LPFO/Gas) (GJ)	PRODUCTION Metric Ton
JAN	110.284	397.022	40.845	1.654	311.25	12730.1	141.539
FEB	74.18	267.048	37.52	1.52	223.93	9158.737	138.472
MAR	108.3	389.88	63.273	2.563	232.24	9498.616	136.911
APR	81.22	292.392	60.73	2.46	251.135	10271.42	140.124
MAY	104.42	375.912	67.045	2.715	263.48	10776.33	141.672
JUN	104.26	375.336	55.3	2.24	281.891	11529.34	142.39
JUL	95.01	342.036	57.005	2.309	215.12	8798.408	139.643
AUG	90.92	327.312	29.765	1.205	172.51	7055.659	135.098
SEP	92.2	331.92	32.99	1.336	172.51	7055.659	139.641
OCT	118.22	425.592	32.94	1.334	188.867	7724.66	142.421
NOV	116.14	418.104	11.224	455	193.201	7901.921	145.007
DEC	118.731	427.4316	34.636	1.403	260.41	10650.77	155.55
TOTAL	1213.885	4369.986	523.273	21.193	2766.544	113151.7	1698.468

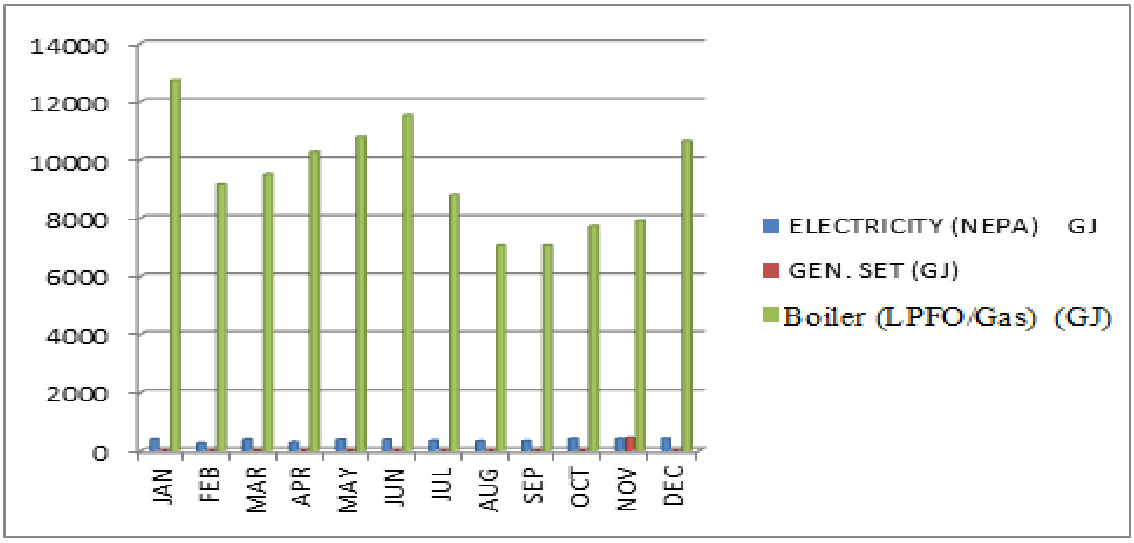

Table 4. Energy consumption and production output (2013)

Table .2, and figure 4. show that in 2013, Boiler (LPFO/Gas) supplied 96.26 % of total energy consumed by the plant. PHCN supplied 3.87 % of total energy while diesel driven Generator supplied 0.037 % of the total energy. It can be seen that diesel driven Generator made the least contribution which perhaps might be due to the high cost of diesel when compared with that of LPFO/gas powered boilers in Nigeria market. The 3.87 % contributed by PHCN is insignificant relative to that made by LPFO/Natural Gas. This also is does not encourage production amd manufacturing ventures in Nigeria, because energy being a vita requirement inadequate and expensive as well.

Table 3. Energy consumption and production output (2014)

Period MONTH	ELECTRICITY (NEPA) (kwh)	ELECTRICITY (NEPA) (GJ)	GEN. SET FUEL(DIESEL)vol. (ltr)	GEN. SET (GJ)	BOILER (LPFO/Gas) vol. (ltr)	BOILER (LPFO/Gas) (GJ)	PRODUCTION Metric Ton
JAN	116.924	420.926	4.25	172	30.873	1262.71	100.75
FEB	119.6	430.56	30.13	1.22	207.038	8467.854	136.764
MAR	118.63	427.068	26.58	1.076	175.425	7174.883	134.631
APR	121.28	436.608	44.219	1.791	179.602	7345.722	135.125
MAY	119.35	429.66	45	1.823	220.245	9008.021	138.113
JUN	112.68	405.648	8.01	324	194.836	7968.792	129.843
JUL	129.61	466.596	9.27	375	72.457	2963.491	110.536
AUG	139.87	503.532	985	40	126.77	5184.893	132.59
SEP	116.1	417.96	8.6	348	109.629	4483.826	128.319
OCT	262.922	946.5192	49.077	1.988	193.3	7905.97	133.354
NOV	332.671	1197.616	49.197	1.992	125.271	5123.584	141.109
DEC	277.22	997.992	43.128	1.747	191.936	7850.182	132.764
TOTAL	1966.857	7080.685	318.446	12.897	12.897	74739.92	1319.927

KEY: LPFO (LOW POUR FUEL OIL)

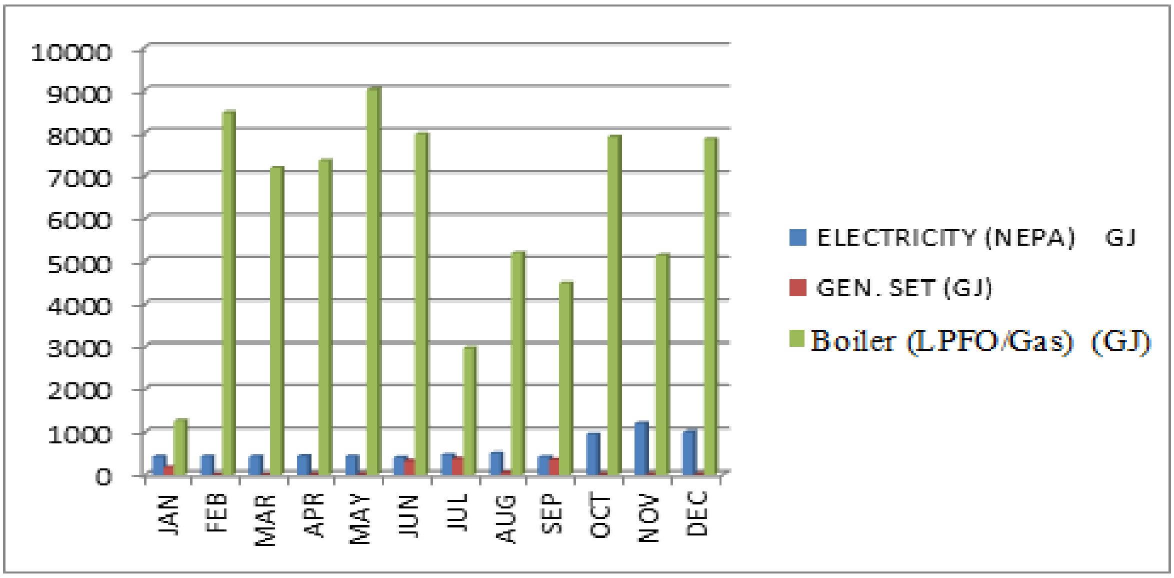

Figure 5. Energy consumption and production output (2014)

Table 3, and Figure 5, show that in 2014, Boiler (LPFO/ natural Gas) supplied 91.33 % of total energy consumed by the plant. PHCN supplied 8.65 % of total energy while diesel driven Generator supplied

0.016 % of the total energy. Here the 8.65 % contributed by PHCN is just a one-tenth of contribution made by Boiler fired by LPFO/natural gas. From these trends it is expedient on the part of the federal government to site more electricity generating plants, efficiently manage the existing power facilities and to encourage private sector participation in Electricity generation, Transmission and distribution in Nigeria.

Table 4. Energy consumption and production output (2015)

Period MONTH	ELECTRICITY (NEPA) (kwh)	ELECTRICITY (NEPA) (GJ)	GEN. SET FUEL(DIESEL) vol. (ltr)	GEN. SET (GJ)	BOILER (LPFO/Gas) vol. (ltr)	BOILER (LPFO/Gas) (GJ)	PRODUCTION Metric Ton
JAN	364,677	1312.84	51,430	2083	145,822	5294.65	301,486
FEB	263,461	948.46	45,777	1854	42,442	1681.76	295,723
MAR	277,188	997.8768	24,400	988	106,613	4125.923	288,946
APR	310,311	1117.12	6570	266	78,347	3032.029	290,110
MAY	301,817	1086.541	19,465	788	95,547	3697.669	320,228
JUN	310,116	1116.418	30,355	1229	74,373	2878.235	319,520
JUL	261,449	941.2164	24,540	994	81,091	3138.222	305,054
AUG	226,369	814.9284	40,900	1656	86,931	3364.23	298,760
SEP	271,425	977.13	24,540	994	65,851	2548.434	299,459
OCT	216,497	779.3892	60,825	2463	96,150	3721.005	302,428
NOV	317,885	1144.386	32,775	1327	96,456	3732.847	318,230
DEC	251,872	906.7392	63,210	2560	110,264	4267.217	310,734
TOTAL	3,373,067	12143.04	424,787	17,204	1,079,887	41482.22	3,650,678

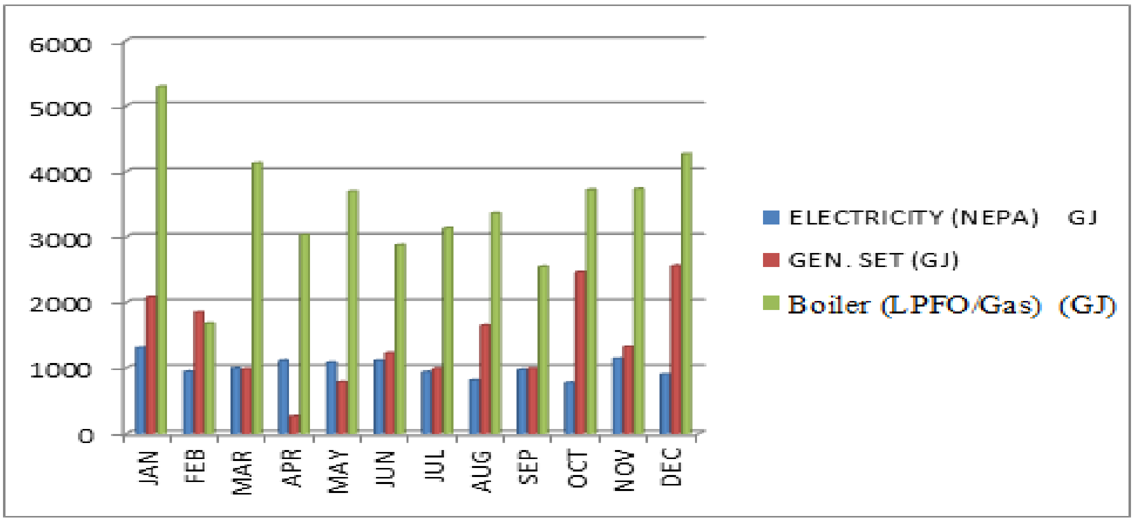

Figure 6. Energy consumption and production output (2015)

Table 4. and Figure 6. Show that in 2015, Boiler (LPFO/Gas) supplied 58.57 % of total energy consumed by the plant. PHCN supplied 17.14 % of total energy while diesel driven Generator supplied 24.23 % of the total energy. Here it can be observed that PHCN supply increased by about 9.5% over the previous year, this will in turn enhance production, reduce production, selling price of sugar to consumers and subsequently increase the quantity demand for surgar as well increased tarrif for the government.

Table 5. Energy consumption and production output (2016)

Period MONTH	ELECTRICITY (NEPA)	ELECTRICITY (NEPA)	GEN. SET FUEL(DIESEL)	GEN. SET (GJ)	BOILER (LPFO/Gas) vol. (ltr)	BOILER (LPFO/Gas) (GJ)	PRODUCTION Metric Ton

	(kwh)	(GJ)	vol. (ltr)				
JAN	310,987	1119.55	83,455	3,380	122,935	4757.58	284,741
FEB	193,810	697.716	36,850	1,492	50,332	1947.848	283,670
MAR	184,436	663.9696	29,960	1,213	47,372	1833.296	287,532
APR	218,332	785.9952	40,196	1,628	84,329	3263.532	288,753
MAY	196,476	707.3136	58,162	2,356	144,988	5611.036	286,470
JUN	190,764	686.7504	42,370	1,716	80,536	3116.743	261,985
JUL	183,147	659.3292	44,300	1,794	38,676	1496.761	279,553
AUG	189,241	681.2676	39,159	1,586	87,610	3390.507	284,043
SEP	254,016	914.4576	40,297	1,632	82,230	3182.301	288,411
OCT	240,683	866.4588	41,011	1,661	93,735	3627.545	286,023
NOV	209,169	753.0084	40,985	1,660	98,858	3825.805	289,642
DEC	302,039	1087.34	51,279	2,077	145,560	5633.172	280,649
TOTAL	2,673,100	9623.16	548,024	22,195	1,077,161	41686.13	3,401,472

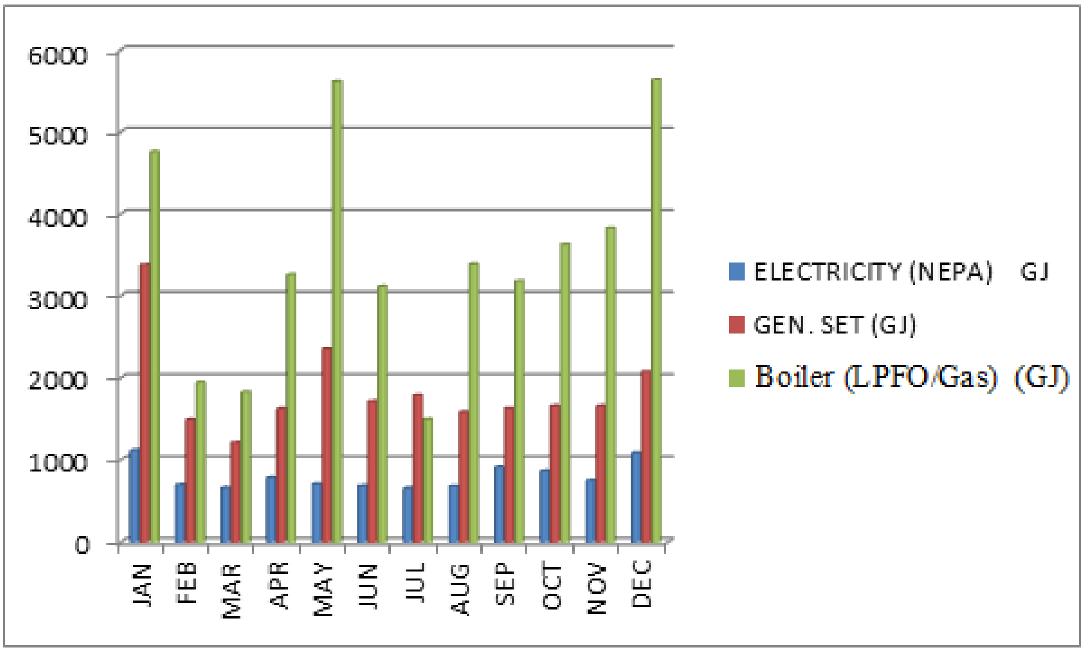

Figure 7. Energy consumption and production output (2016)

Table 5, and Figure 7 respectively show that in 2016, Boiler (LPFO/Gas) supplied 56.71 % of total energy consumed by the plant. PHCN supplied 13.09 % of total energy while diesel driven Generator supplied 30.19 % of the total energy. From this result it can be noticed it can be noticed that there is a slight fall/drop in the percentage of energy contributed by PHCN in 2016 over its that it made in 2015. Meanwhile generator supply increased from 24.23 % in year 2015 to 30.19 % in 20126 amounting to about 5.96 % increment. The LPFO/Natural gas fired boiler and diesel driven generators are supposed to function as back up (stand by) power while PHCN supply ought to be the prime power source, but due the unavailability of the national grid supply, the backup (stand by) are now being relied on for contours production, with attendant effect of increased production cost in most facilities operating Nigeria.

Table 6. Energy efficiency performance result of the factory.

ENERGY PERAMETERS	2012	2013	2014	2015	2016	Average
Total Energy Consumed (MJ)	13733.16	125983.2	94717.61	71441.19	73504.29	100596.8

Production Output (million ton)	1.969	2.351	2.196	3.651	3.401	2.71
Energy Intensity (GJ/m2)	10.72	9.83	7.39	5.58	5.74	7.852
energy Productivity MJ/25kg	69.75	53.58	43.13	19.57	21.61	37.12
Cost of energy input ₦	29.64	44.12	49.47	21.99	28.48	34.74
Normalized performance indicator GJ/m^2	1.36	1.37	1.29	1.04	1	1.2

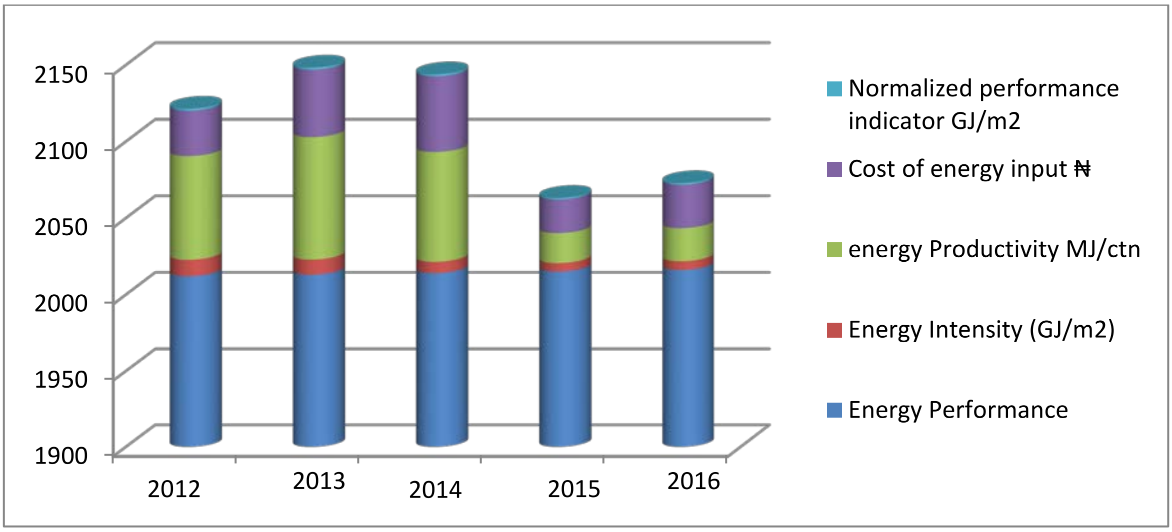

Figure 8: Comparison of different energy efficiency performance parameter

From 137.4 GJ in year 2012 to 71.4 GJ in 2015 and a slight increase in 2006, whereas production output increased from 1.969 million ton in 2012 to 3.651 million ton in 215. This decline may as a result of change in boiler fuel from a less fuel efficient to more fuel efficient one. It is also possible that during this perion that the company applied better energy management and conservation measures. Total energy cost per annum which was expected to drop due to decline in energy consumed rather increased from ₦60.1 million in year 2012 to ₦96.9 million in 2016. This energy cost increase resulted from yearly increase in electricity unit charge by the main power supplier PHCN. Summary of total energy consumed, percentages and cost are Total energy consumed per annum declined presented in Tables 6 to 4.10 and Figure 8.

Table 7.. Summary of total energy consumed.

Year/Energy	2012 (GJ)	2013 (GJ)	2014 (GJ)	2015 (GJ)	2016 (GJ)
Electricity	3690.702	4369.986	7080.69	12143.04	9623.16
LPFO	115680.91	102880.2	74739.92	5294.65	117206.4
AGO		18,733	12,897	17,204	22,195
Gas	17,966			36188.36	41686.13
Total	137337.61	125983.2	94717.61	71441.19	190710.7

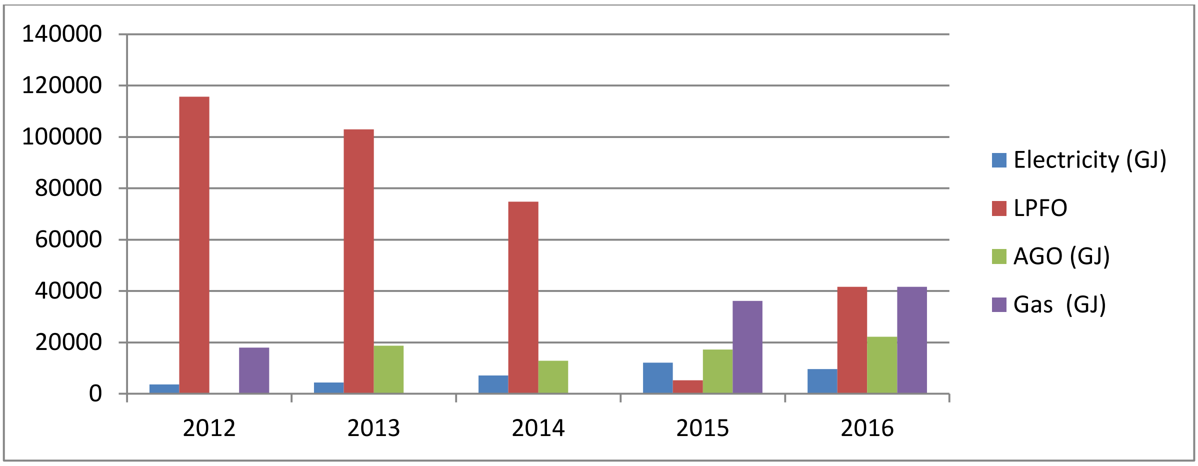

Figure 9: Summary of total energy consumed

Table 7 and Figure 9. show that in year 2012 the company's boilers were completely fired by natural gas and the use of LPFO was phased out that year, perhaps due to high cost of the product. Also result show a steady decline in LPFO consumption between year 2012 and 2015 but recorded a sharp increase between 2015 and 2016. However, Natural gas, LPFO and AGO were all used in years 2015 and 2016 respectively. This is because all three source of energy had fairly stable prices within this period..

Table 8. Summary of percentage Energy consumption

Year	**Electrical Energy percentage consumption**	**LPFO/Natural Gas percentage consumption**	**AGO percentage consumption**
2012	2.69	84.23	13.08
2013	3.47	81.66	14.87
2014	7.48	78.9	13.62
2015	17	50.65	24.08
2016	13.09	56.71	30.2
Average	8.75	72.08	19.17

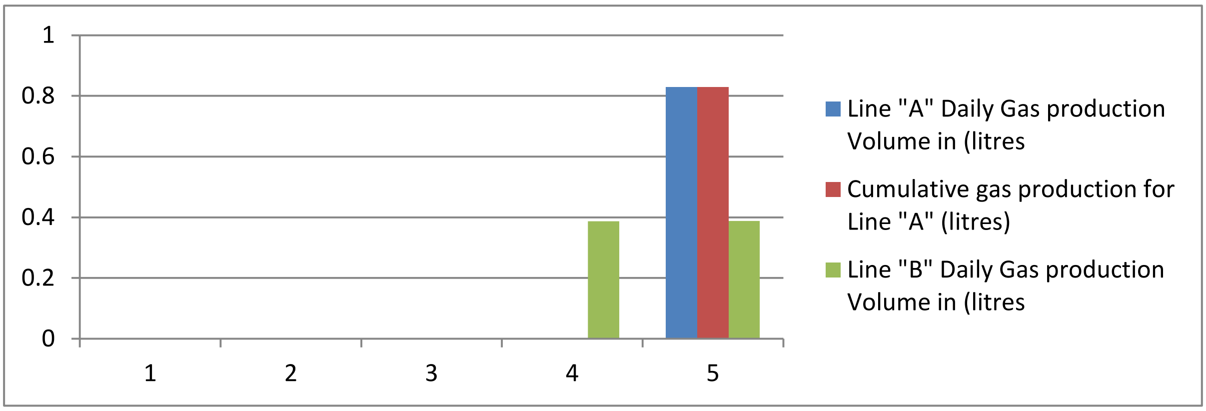

Figure10. Percentage energy consumption graph

Table 8 and Figure 10 indicated that; high percentage consumption of LPFO/Natural Gas throughout the five years covered by this study. It can also be observed that the percentage consumption of AGO increased steadily for the five years. However, PHCN contributed the lowest percentage of energy for the five years studied. If one were to relate to the manageability of cost or cost savings potential in every production process, energy would invariably emerge as a top ranker, and thus energy management constitutes a strategic area for cost reduction, (Cape and Kennedy, 1997). To this end every producer or manufacturer must develope adequate strategies to efficiently manage and conserve its energy resources.

Table 9. Energy cost

Year	**Electricity (N)**	**LPFO (N)**	**AGO (N)**	Natural Gas (N)	Total (N)
2012	7,135,805	39,597,376	13352480	NA	60,085,662
2013	8111212	44,264,704	17111027	NA	69486943
2014	19513241	32,892,876	12897063	NA	65303180
2015	32581624	2,624,796	24212859	20848971	80268250
2016	25,394,450	NA	33977488	37485544	96,857,482
Average	18,547,267	38918319	20310184	29167258	74,400,304

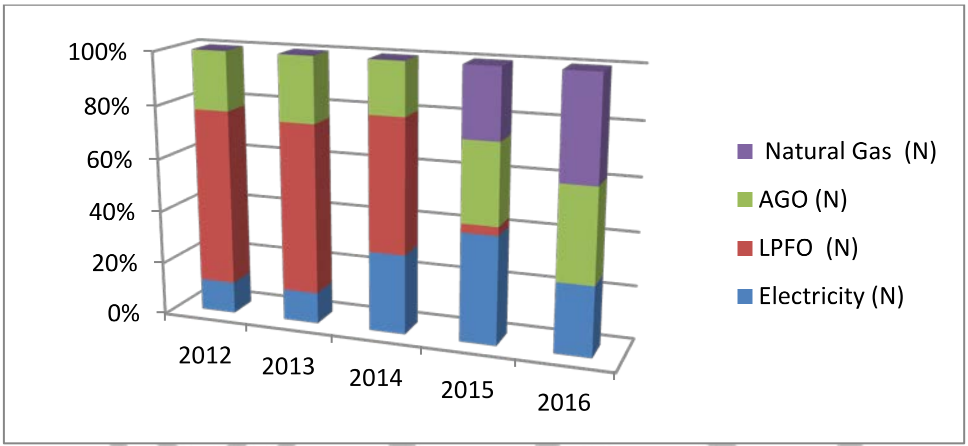

Fig.11. Energy cost comparison

The energy cost on LPFO was highest for the five years as can be seen in Figure 11 and Table 9, with an average of ₦389,183,19. PHCN supply had the lowest average cost of ₦18,547,267 among the four energy sources considered over the five years study period. Natural gas had average cost of ₦291,672,58. While AGO had an average cost of ₦ 203,101,84. Values of Cost of Energy input for the five years (2012-2016) are given in Table 9 and Figure 11 respectively. Average Cost of Energy input per Product was found to N34.72per 25 kg bag of sugar for the five year period.

Table 10. Summary Percentage Energy Cost

Year	**% Electrical Energy Cost**	**% LPFO /Natural Gas Energy Cost**	**% AGO Energy Cost**
2012	13	62	25.22
2013	12.67	60	27.63
2014	30.88	46	22.75
2015	41.59	25	33.17
2016	27	35.64	37.73
Average	25	44.77	29.3

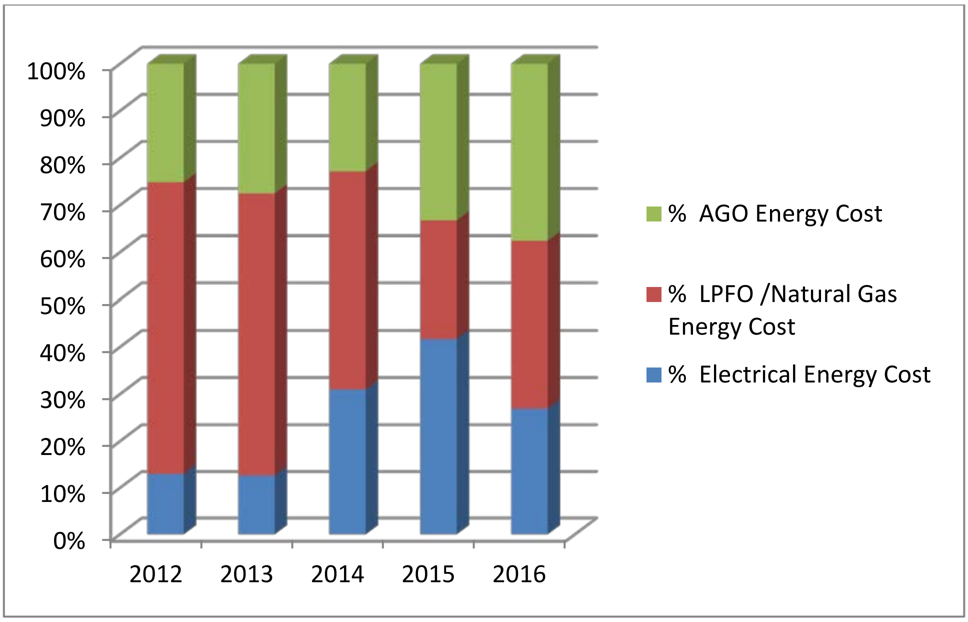

Figure 12 Percentage of energy cost for five years

The Percentage energy cost on LPFO/ Natural gas was highest for the five years as can be seen in Table 10 and Figure 12 with an average of 44.77 %. While Percentage of energy cost on AGO and PHCN supplied electricity had average of 29.3 and 25 % respectively.

9. Conclusion

i. That for a treated floor area of 128,13.57 m2 over a five- year period (2012-2016), average annual energy consumption of 100596.78 GJ was obtained.

ii. . This consumption was made up of 8.75% of Electricity supplied by PHCN, 72.08% was for LPFO/Natural Gas and 19.17% was for self-generated electricity using diesel fired generators while in terms of energy cost, electricity, LPFO/Gas and diesel accounted for 24.93%, 45.76% and 29.3% respectively.

iii. Average annual production output (million cartons) for the five years studied was 2.407 while the NPI (normalized performance Indicator) for the factory in GJ/m2 was 1.2 which is in the "fair" range indicating that there is still room for improvement (D. K. Hale, D. Vincent and P. T. Clarke, 1979) in terms of energy utilization and savings.

iv. Average Intensity of energy (GJ/m2) was 7.852 while average energy productivity in (MJ/Bag) was 52.14.

v. The Average cost of energy input/product was calculated to be N34.74/Bag with the lowest value of N21.99/Bag in year 2014.

vi. The average cost of annual consumption was found to be N 74.40 million while an average yearly savings on fuel in boiler, improved feed water quality, reduction in com- pressed air pressure and improved boiler efficiency to 75.3% would amount to N4.3 million.

vii. The Normalized performance Indicator (NPI) values calculated for the period of five years gave an average of 1.2 GJ/m^2, this indicated a "fair" range which implies an average performance (Chartered Institution of Building Services, 1982), while significant savings and improvement in energy usage is achievable. There is room for improvement to a satisfactory and good classification range.

10. RECOMMENDATIONS

Base on the findings of this study the following recommendations were made;

1. To install electric meters in major production and administrative units to monitor/curtail power wastages in each unit thereby reducing energy cost of power.
2. Improve boiler feed water quality to eliminate cost incurred in extra blow down.
3. Raise boiler efficiency by reducing flue gas losses and other losses.
4. Reduce steam leakages along pipelines and improve lagging of steam pipes.
5. Procurement of test equipment for energy monitoring in the factory.
6. Good maintenance and control must be put in place in order to improve the energy performance of the plat and rating to be good.
7. Motivation for energy conservation activities among the sugar refinery workers.
8. Significant capital investment should be made in re- placement of inefficient energy consuming equipment to reduce the energy consumption.

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