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ENERGY AUDIT OF A FLOUR MILL PLANT: A CASE STUDY OF CROWN FLOUR MILL PLC

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ABSTRACT

In Nigeria today, many production industries are faced with challenges of utilizing energy efficiently. Hence, for industries to utilize energy efficiently, a proper energy audit should be carried out on its production processes. This paper assesses an energy audit of the 2015 production year of Crown Flour Mill Plant A and Plant B. Data was collected from the processing mills, A and B, to determine the energy consumption rate in the Milling Plants. From the results, it was determined that the roller mill machines in Mill A and B consumes the largest quantity of energy which is 32,078,200MJ/year and 20,808,191.27MJ/year respectively. This accounts for 91.8% and 62.6% respectively of energy consumed in the both plants. The purifier machine in Mill A and the blower standby machine in Mill B are the least consumer of energy among the process machines used in the flour production process. This accounts for 0.13% and 0.14% of the energy consumption. The calculated amount of diesel fuel energy consumed was about 18.4GWh/year and 29.5GWh/year for Mill A and B respectively, which is a total of 47.9GWh/year. However, the energy requirement of the process machines and consumption capacities for Mills A and B was a total of 14.1GWh/year which is far lesser than the energy generated from the diesel fuel used. Hence, a lot of energy is being wasted in the flour production plants.

1. INTRODUCTION

Energy is an integral component of a modern economy. Essentially, its use extracts heavy financial, environmental and security cost (Oyedepo and Aremu, 2013). In its use, energy loss remains pertinent, thus an increase in energy cost prevail. Therefore, an efficient use of energy becomes necessary in order to reduce energy cost while still benefiting from it. Energy in its different forms is required as a continuous input to all industrial processes (Morvay and Gvozdenac, 2008**)**. The losses of energy during its uses in industrial processes are inevitable, this is due to designs that do not incorporate energy efficient specifications such as heat recovery options, operation that run on inefficient method and lastly, poor or non-energy efficiency conscious maintenance program (Agbro, 2007). Thus, reducing energy losses will substantially increase plant efficiency. However, data is needed to identify and quantify the losses and subsequently suggest techno-economic solutions to minimise the losses. This data can be acquired through an energy audit.

The concept of energy audit was born shortly after the oil energy crises in the early 1970's. At that time, there were many inefficient uses of energy. An energy auditor has a job of identifying opportunity for saving energy. The challenge before an energy auditor is to increase or at least maintain the physical/economic situation at a reduced level of energy consumption (Agbro, 2007). The energy auditor's target is to simply identify the areas and processes by which energy is consumed the most. In other words, energy consumption pattern must be surveyed, thus providing the base for determining where to search for significant reductions in usage. The need for energy auditing cannot be over-emphasized. Proper analysis of information obtained from an energy audit can help make decisions that will reduce energy bills for industries, households and businesses, and can boost the economy in a sector with great potential for future growth, driving innovation in the process. The prospect of achieving more with less energy is an exciting one, and this strategy sets out the opportunity in full (Aiyedun and Ologunye, 2001).

In Nigeria today, many production and manufacturing industries are faced with challenges of utilizing energy efficiently. This study was carried out to audit the energy consumption rate of Milling Plants A and B of Crown Flour Mill, Apapa Nigeria.

2. METHODOLOGY

2.1. Data Collection

Data was collected from the milling plants which are A and B for the production year 2015. Tables 1 and 2 represents the energy consuming machines in the flour mill production plants A and B while Tables 3 and 4 represents the monthly run hours of process machines for milling A and B.

Table 1: Energy consuming machines in the flour mill production Plant A

Name of Machines	No. of Machines	Type of Machine	Motor Specification			Power Rating (kW)
			Rpm	Amp (A)	Cos ø	
Tempering Bin	3	Electric Motor				5.5
Roller Mills	28	Electric Motor	980	56	0.84	30
Plansifter	4	Electric Motor	980			4
Minisifter	2	Electric Motor	1400			2.2
Purifier	2	Electric Motor	1895	2.8	0.8	1.1
Bran Finisher	2	Electric Motor	1450	15		7.5
Detacher	13	Electric Motor	1440	21.5		5.5
Sterilator	2	Electric Motor	2939	1.5	0.85	5.5
Air Lock Cyclone	6	Electric Motor	1450	2.65	0.78	1.1
High Pressure fan	5	Electric Motor	1440	21.5		5.5

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Table 2: Energy consuming machines in the flour mill production Plant B

Name of Machines	No. of Machines	Type of Machine	Motor Specification			Power Rating(kW)
			Rpm	Amp (A)	Cos ø	
1st Tempering Bin	2	Electric Motor				3.0
Aspirator	4	Electric Motor				1.1
Damper	2	Electric Motor	1755	21.5	0.87	12.5
2nd Tempering Bin	3	Electric Motor				3
Elevator	1	Electric Motor				3
Roller Mills	42	Electric Motor	960	29.5		30
Plan Sifter	4	Electric Motor	1400			11
Purifier	4	Electric Motor				0.75
Bran Finisher	8	Electric Motor				5.5
Detache	16	Electric Motor	2935	19.5		11
After Cyclone Air	8	Electric Motor	1710	3.7	0.78	1.5
High Pressure Fan	2	Electric Motor	2983	190	0.9	110
Filter Fan	1	Electric Motor	2985	31.5	0.89	18.5
Sterilator	2	Electric Motor	2955	60	0.88	37
Blower	1	Electric Motor	2920	26.5	0.9	15
Blower Standby	1	Electric Motor	2920	14.5	0.89	14.5
Low Pressure Fan	3	Electric Motor				18.5
Rinsing Air Machine	2	Electric Motor	2920	26.5	0.9	15

Table 3: Monthly run hours of process machines for milling Plant A

Name of Machines	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tempering Bin	528	530	542	525	531	570	571	545	548	549	550	502
Roller Mills	672	685	675	669	669	690	692	666	692	693	695	652
Plansifter	548	550	557	545	545	561	559	544	568	569	569	528
Minisifter	612	620	628	609	609	632	629	609	632	631	634	593
Purifier	620	628	632	616	617	642	640	618	640	641	642	602
Bran Finisher	615	625	628	612	612	622	619	612	635	630	637	598
Detacher	550	556	561	547	547	561	560	548	570	571	572	530
Sterilator	600	610	613	592	597	626	624	598	620	622	623	580
Air Lock Cyclone	560	572	578	556	557	571	569	557	580	581	582	542
High Pressure fan	610	618	627	607	603	623	621	608	630	631	632	589

Table 4: Monthly run hours of process machines for milling Plant B

Name of Machines	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st Tempering Bin	610	608	609	620	628	608	615	613	620	633	628	579
Aspirator	615	613	613	625	631	613	620	617	625	634	630	580
Damper	624	621	625	634	638	622	629	626	644	655	642	592
2nd Tempering Bin	610	607	605	620	630	608	615	612	630	631	630	579
Elevator	598	595	595	609	620	595	603	600	610	626	622	578
Roller Mills	595	592	592	615	617	593	600	598	609	618	619	575
Plan Sifter	605	602	600	615	615	603	610	607	615	627	620	570
Purifier	612	610	610	622	632	610	617	615	622	635	632	590
Bran Finisher	632	630	623	642	652	630	637	634	642	655	652	602
Detacher	590	587	599	610	610	588	595	592	600	620	612	560
After Cyclone Air	592	590	601	609	619	590	597	595	612	613	615	562
High Pressure Fan	610	608	619	620	630	608	615	613	620	632	625	583
Filter Fan	603	601	611	613	623	601	608	605	613	625	623	586
Sterilator	598	593	600	603	610	596	564	599	618	620	610	561
Blower	510	507	518	520	540	508	515	513	520	535	530	485
Blower Standby	110	108	119	120	130	108	115	112	120	135	130	85
Low Pressure Fan	560	558	569	570	580	561	565	562	570	589	580	530
Rinsing Air Machine	587	584	585	597	597	585	592	588	597	615	601	538

2.2. Data Analysis

The following analyses were carried out on the energy audit data collected (Ali et al., 2010):

2.2.1. Electrical energy consumption

The quantity of electricity used by the machines in each Milling plant is determined using equation (1):

$$E = \frac{3.6PL_f t}{\eta_m} \quad (1)$$

Where: E = electrical energy consumption in MJ; P = power in kW; t = time in h; η_m = motor efficiency; L_f = electrical load factor

2.2.2. Load factor

The load factor is the ratio of the load that a piece of electrical equipment actually utilized when it is in operation to the maximum load it could utilize (which we call full load). The electrical load factor of a motor was determined from Equation (2).

$$\text{Load factor} = \frac{\text{actual load current}}{\text{full load current on nameplate}} \quad (2)$$

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2.2.3. Diesel fuel consumption

Energy from the diesel fuel consumed by the different milling machines was evaluated using Equation (3):

$$Q = m_{fu,d} \times CV \tag{3}$$

Where: Q = diesel fuel energy consumption; $m_{fu,d}$ = mass of diesel fuel (kg); CV = the calorific value of the diesel fuel (kJ/kg)

2.2.4. Specific energy consumption

The specific energy consumption of the different machines in each of the production mill was evaluated using Equation (4).

$$\text{Specific Energy Consumption(SEC)} = \frac{\text{energy consumed}}{\text{production output}} \tag{4}$$

Where: specific energy consumption, $SEC = MJ/kg$

2.2.5. Electrical load equation

The electrical load of each milling plant was evaluated using Equation (5).

$$\text{Electrical load} = \frac{\text{energy input (kWh)}}{\text{period of operation(h)}} \tag{5}$$

2.2.6. Actual percentage process

The actual percentage process is the percentage ratio of energy consumed by equipment to the total energy consumed by all the equipment in that process over a period of time.

$$\text{Actual \% Process} = \frac{\text{Energy Consumed by an equipment (kWhr/yr)}}{\text{Total Energy Consumed by all equipment(kWhr/yr)}} \tag{6}$$

3. RESULTS AND DISCUSSION

Tables 5 and 6 show the summary of the total electrical energy consumed in the different process machines in mills A and B.

Table 5: Summary of the total electrical energy consumption of the different process machines in mill a for the flour manufacturing processes in 2015

Manufacturing process Machines	Energy consumption (kWh/yr.)	Energy consumption (MJ/yr.)	Actual % process
Tempering Bin	73632.28	265076.25	1.54
Roller Mills	3978405.00	32078200	83.41
Plansifter	70415.80	253496.88	1.48
Minisifter	22481.11	80999.82	1.69
Purifier	10480.44	45992.12	0.22
Bran Finisher	76776.58	276395.65	1.61
Detacher	328019.68	1180870.77	6.88
Sterilator	52410.05	188337.62	1.09
Air Lock Cyclone	29844.89	107117.50	0.63
High Pressure fan	127170.64	457813.15	2.67
Total	4769636.47	34934299.76	100

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Table 6: Summary of the total electrical energy consumption of the different process machines in mill b for the flour manufacturing processes in 2015

Manufacturing process machines	Energy consumption (kWh/yr)	Energy consumption (MJ/yr)	Actual % process
1st Tempering Bin	29380.31	105769.12	0.31
Aspirator	22475.85	80913.06	0.24
Damper	110011.61	39641.79	1.17
2nd Tempering Bin	43985.39	158347.40	0.47
Elevator	14139.45	50902.02	0.15
Roller Mills	5780053.13	20808191.27	61.9
Plan Sifter	217043.61	781356.00	2.32
Purifier	13888.14	49997.30	0.15
Bran Finisher	230837.75	831015.90	2.47
Detacher	825167.20	2970601.92	8.84
After Cyclone Air Lock	57200.25	205920.90	0.61
High Pressure Fan	1116678.75	4020043.50	11.96
Filter Fan	92998.50	334794.60	0.99
Sterilator	333740.00	1201464.00	3.57
Blower	61622.43	221840.75	0.66
Blower Standby	13796.76	49668.34	0.15
Low Pressure Fan	235666.91	848400.88	2.52
Rinsing Air Machine	140079.03	504284.51	1.49
Total	9338765.07	33263153.26	100

3.1. Diesel Fuel Energy Consumed in Mills A and mill B

Diesel Generator Operating Data

Fuel Type = Diesel
Diesel Consumption Rate = 12600 litres/day
Speed = 1500 rpm (Company's Handbook)

Flour Mill A:

Mill A is a smaller mill, thus consumes lesser quantity of diesel compared to Mill B.
Fuel Consumption = 4850 litres/day
Volume of diesel fuel used in 2015 = 4850 × 332days = 1610200litres/year

Thus, volume of diesel fuel in m^3/year used in 2015 = $1610200 \times \frac{1}{1000}$ = 1610.2 m^3/year

Density of diesel fuel:

The relative density of diesel fuel = 0.95 (The Engineering Toolbox, 2016)

The density of water = 1000kg/m^3

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Hence:

$$\text{Density of diesel fuel} = \text{density of water} \times \text{relative density of diesel fuel} \quad (7)$$

Density of diesel fuel = 0.95 × 1000 kg/m^3 = 950 kg/m^3

Mass of diesel fuel:

$$\text{Mass of diesel fuel} = \text{density of fuel} \times \text{volume of diesel fuel} \quad (8)$$

Mass of diesel fuel = 950 × 1610.2 = 1529690kg/yr.

However, the calorific value of diesel fuel, CV is:

CV = 43400kJ/kg = 43.4MJ/kg (NIST Chemistry WebBook, 2014)

In calculating the thermal energy consumed from the diesel fuel per year, Equation (3) was used:

$E = m_{fu,d} \times CV$

E = 1529690 × 43.4 = 66388546MJ/yr.

But, 1kWh = 3.6MJ

Thus, $E = 66388546 \times \frac{1}{3.6}$

E = 18441262.78kWh/yr.

Hence, the thermal energy consumed from the diesel fuel per year E = 18441262.78kWh/yr.

Flour Mill B:

Fuel Consumption = 7750 litres/day
Volume of diesel fuel used in 2015 = 7750 litres /day × 332days = 2573000litres
Volume of diesel fuel used in 2015 = $2573000 \times \frac{1}{1000}$ = 2573 m^3/year
Density of diesel fuel:
The relative density of diesel fuel = 0.95
The density of water = 1000kg/m^3

Hence:
Density of diesel fuel = density of water × relative density of diesel fuel
Density of diesel fuel = 0.95 × 1000 kg/m^3 = 950 kg/m^3
Mass of diesel fuel:
Mass of diesel fuel = density of fuel × volume of diesel fuel
Mass of diesel fuel = 950 × 2573 = 2444350kg/yr.

However, the calorific value of diesel fuel, CV is:

CV = 43400kJ/kg = 43.4MJ/kg (NIST Chemistry Web-Book, 2014)

In calculating the thermal energy consumed from the diesel fuel per year, Equation (3) was used:

$$E = m_{fu,d} \times CV$$

E = 2444350 × 43.4 = 106084790MJ/yr.

But, 1kWh = 3.6MJ

Thus:

$$E = 106084790 \times \frac{1}{3.6} = 29467997.22\text{kWh/yr.}$$

Hence, the thermal energy consumed from the diesel fuel per year E = 29467997.22kWh/yr.

Total Energy Consumed from Diesel Fuel from both Mills is:

18441262.78 + 29467997.22 = 47909260kW/yr.

3.2. Cash Equivalent of The Diesel Fuel Consumption in Mill A

Diesel fuel consumed = 4850litres/day

Cost of diesel = N210.00/litre

Thus:

Cost of diesel fuel consumed per day = 4850litres/day × N210.00/litre = N1018500.00

Therefore, the total cost of diesel fuel consumed per year (working days) is:

Cost of diesel fuel consumed by Mill A in 2015 = N1018500.00 × 332 = N338, 142,000

3.3. Cash Equivalent of the Diesel Fuel Consumption in Mill B

Diesel fuel consumed = 7750litres/day

Cost of diesel = N210.00/litre

Thus, cost of diesel fuel consumed per day = 7750litres/day × N210.00/litre = N1627500

Therefore, the total cost of diesel fuel consumed per year (working days) is:

Cost of diesel fuel consumed by Mill B in 2015 = N1627500 × 332 = N540, 330,000

Total cost of diesel fuel for Mill A and B = N338, 142,000 + N540, 330,000

Therefore, diesel fuel for Mill A and B = N878, 472,000

3.4. Exhaust Gas Heat Loss, Q_{net}, from the Diesel Generator

Data:

Mass flow rate of the diesel fuel $\dot{m}_{fu,d}$ = 525kg/hr. = 0.146kg/s (Cummins Generator Specification Manual)

Ambient temperature: $30^oC = 303K$

Temperature of combustion products (exhaust gases) leaving diesel generator: 460^{o}C= 733K

Specific heat capacity of exhaust gas: 1.15kJ/kgK

Stoichiometric equation of the combustion of the diesel fuel;

$$4C_{12}H_{23} + 71O_2 + \left(71\,x\frac{79}{21}\right)N_2 \rightarrow 48CO_2 + 46H_2\left(71\,x\frac{79}{21}\right)N_2 \quad (9)$$

4 kmol of fuel has a mass of 4 (144 + 23) kg = 668kg;

71 kmol of oxygen have a mass of (71 x 32) kg = 2272kg

O_2 required per kg of fuel = 2272/668 = 3.401

Therefore, Percentage Mass composition of oxygen in air = 0.233

$\text{Stochiometric air} - \text{diesel fuel ratio} = \frac{3.401}{0.233}$ = 14.5974

Assuming a mixture strength of 90%

$$\text{Mixture Strength} = (\text{Stoichiometric A/F ratio}) / (\text{Actual A/F ratio}) \quad (10)$$

0.9 = 14.595/Actual A/F ratio

Therefore, Actual A/F ratio = 14.595/0.9 = 16.218

This means that 1/0.9 times as much air is supplied as is necessary for complete combustion.

The exhaust will therefore contain (1/0.9) – 1 = 0.1/0.9 of the stoichiometric oxygen.

$$C_{12}H_{23} + 71O_2 + \left(71\,x\frac{79}{21}\right)N_2 \rightarrow 48CO_2 + 46H_2O + \left(71\,x\frac{0.1}{0.9}\right)O_2 + \left(71\,(\frac{0.1}{0.9})\,(\frac{79}{21})\right)N_2 \quad (11)$$

i.e. the products are: 48kmolCO_2 + 46 kmol H_2O + 7.89kmolO_2 + 296.773N_2

The total amount of substance = 48 + 46 + 7.89 + 296.773 = 398.7kmol

Hence wet analysis is:

(48/398.7) x 100 = 12.04% CO_2
(46/398.7) x 100 = 11.54% H_2O
(7.89/398.7) x 100 = 1.98% O_2
(296.773/398.7) x 100 = 74.44% N_2
The total dry amount of substance = 48 + 7.89 + 296.773 = 352.663kmol
Hence the dry exhaust gas analysis is:
(48/352.663) x 100 = 13.61% CO_2
(7.89/352.663) x 100 = 2.24% O_2
(296.773/352.663) x 100 = 84.15%N_2

To obtain the mass flow rate of the combustion product, $\dot{m}_{g,exh}$

$$\text{mass flow rate of air}, \dot{m}_a = m_{fuel} \times AF \quad (12)$$

$$\text{mass flow rate of air}, \dot{m}_a = 0.146 \times 16.218 = 2.368 \text{ kg/s}$$

$$\text{therefore}, \dot{m}_{g,exh} = \dot{m}_a + m_{fuel} \quad (13)$$

$$\dot{m}_{g,exh} = 2.368 + 0.146 = 2.514\text{kg/s}$$

$$\text{Exhaust gas heat loss}, Q_{exh} = \dot{m}_{g,exh} C_{pg}\left(T_{g,exh} - T_{amb}\right) \quad (14)$$

$$Q_{exh} = 2.514 \times 1.15 \times 10^3 (733 - 303) = 1243.17\text{kW}$$

Therefore, the exhaust heat loss, Q_{net}, from the diesel generator set = 1243.71kW

3.5. Specific Energy Consumption

To determine the specific energy consumption of the different process machines for the different flour manufacturing processes, Equation (4) was used. Table 7 and Table 8 show the specific energy consumption of the flour manufacturing process machines for Mill A and Mill B respectively in 2015.

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Table 7: Flour manufacturing process machines specific energy consumption (MJ/kg) for Mill A

Manufacturing process Machines	Energy consumption (kWh/yr.)	Energy consumption (MJ/yr.)	Production Output (kg/year)	Specific Energy Consumption, SEC, (MJ/kg)
Tempering Bin	73632.28	265076.25	64258600	0.0041
Roller Mills	3978405.00	32078200	64258600	0.4992
Plansifter	70415.80	253496.88	64258600	0.0039
Minisifter	22481.11	80999.82	64258600	0.0013
Purifier	10480.44	45992.12	64258600	0.0007
Bran Finisher	76776.58	276395.65	64258600	0.0043
Detacher	328019.68	1180870.77	64258600	0.0184
Sterilator	52410.05	188337.62	64258600	0.0029
Air Lock Cyclone	29844.89	107117.50	64258600	0.0017
High Pressure fan	127170.64	457813.15	64258600	0.0071
Total	4769636.47	34934299.76		0.5436

Table 8: Flour manufacturing process machines specific energy consumption (MJ/kg) for mill B

Manufacturing process machines	Energy consumption (kWh/yr.)	Energy consumption (MJ/yr.)	Production Output (kg/yr.)	Specific Energy Consumption (MJ/kg)
1st Tempering Bin	29380.31	105769.12	102820400	0.0010
Aspirator	22475.85	80913.06	102820400	0.0008
Damper	110011.61	39641.79	102820400	0.0004
2nd Tempering Bin	43985.39	158347.40	102820400	0.0015
Elevator	14139.45	50902.02	102820400	0.0005
Roller Mills	5780053.13	20808191.27	102820400	0.2023
Plan Sifter	217043.61	781356.00	102820400	0.0076
Purifier	13888.14	49997.30	102820400	0.0005
Bran Finisher	230837.75	831015.90	102820400	0.0081
Detacher	825167.20	2970601.92	102820400	0.0289
After Cyclone Air Lock	57200.25	205920.90	102820400	0.0020
High Pressure Fan	1116678.75	4020043.50	102820400	0.0039
Filter Fan	92998.50	334794.60	102820400	0.0033
Sterilator	333740.00	1201464.00	102820400	0.0117
Blower	61622.43	221840.75	102820400	0.0022
Blower Standby	13796.76	49668.34	102820400	0.0005
Low Pressure Fan	235666.91	848400.88	102820400	0.0083
Rinsing Air Machine	140079.03	504284.51	102820400	0.0049
Total	9338765.07	33263153.26		0.2884

3.6. Monthly Production Specific Energy Consumption for Mill A and Mill B

The data presented in Table 5 was analysed using Equations (3) and (4), and the results obtained are presented in Table 9.

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Table 9: Monthly production specific energy consumption (SEC)

Month	No of working	Total Production output (kg)	Diesel fuel Quantity (litre)	consumption Fuel energy (MJ)	SEC MJ/kg
Jan.	27	13587750	340200	14206446	1.046
Feb.	24	12078000	302400	12467952	1.032
March	28	14091000	352800	14545944	1.032
April	29	14594250	365400	15065442	1.032
May	27	13587750	340200	14026446	1.046
June	26	13084500	327600	13506948	1.032
July	26	13084500	327600	13506948	1.032
Aug.	31	15600750	390600	16104438	1.032
Sept.	30	15097500	378000	15584940	1.032
Oct.	30	15097500	378000	15584940	1.032
Nov.	29	14594250	365400	15065442	1.032
Dec.	25	12581250	315000	12987450	1.032
Total	332	167079000	3326400	172473336	12.412

3.7. Summary of Annual Production Specific Energy Consumption for Mills A and B

Table 10 shows the summary of annual production specific energy consumption (SEC) for mills A and B.

Table 10: Summary of Annual Production Specific Energy Consumption for Mills A and B

Year	Production output (kg)	Fuel energy (SEC), MJ/kg
2015	167079000	12.412

3.8 Electrical load analysis

The analyses of the electrical load used for the study was determined using Equation (5), by inputting energy input data obtained from diesel fuel consumption into the equation. Table 11 is the summary of the results of the electrical load analysis of Mills A and B.

Table 11: Summary of electrical load analysis

Year	Energy (kWh)	Period (hours)	Electrical load (kW)
2015	47909260(diesel fuel)	7968	6013

3.9. Energy cost of manufacturing a bag of flour

$$\text{Cost per kg} = \frac{\text{Total Annual Energy Cost(N)}}{\text{Annual Production Output(kg)}} \qquad (15)$$

Cost per kg = N 878,472,000 / 167079000 = N 5.26k per kg

Therefore, energy input price per bag is:

A bag of flour is 50kg, therefore: Energy input/bag = 50 × N5.26 = N263.00k

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3.10. Specific Energy Consumption of Manufacturing a Bag of Flour

From Table 11:

Total energy consumption = 47909260 kWh = 172473336MJ

Total Production = 167079000kg

Hence, specific energy consumption per kg = 172473336 / 167079000 = 1.032MJ/ kg

3.11. Energy Efficiency Performance

Energy efficiency performance results are shown in Table 12.

Table 12: Energy efficiency performance result

Parameters	Data Obtained
Total energy consumed	172473336MJ
Total cost of energy consumed	N 878,472,000
Total production output	167079000kg
Specific energy consumption	1.032MJ/kg of flour
Specific energy cost	N 5.26/kg of flour

From the result and investigations of the energy audit carried out in the flour manufacturing factory, the following were observed:

The total energy consumed (diesel fuel) in the entire plant over the one-year period (2015) is 172473336MJ. This shows that the plant totally depends on diesel fuel. The calculated amount of diesel fuel energy consumption is about 18441262.78kWh/year and 29467997.22kWh/year for Mill A and B respectively, which is a total of 47909260 kWh/yr. However, when compared to the calculated energy requirement from the process machines capacities which are 4769636.47kWh/year and 9338765.07kWh/year for Mill A and B respectively, a total of 14108401.54kWh/year for the period under study, it can be deduced that there was over consumption of energy. Hence, a lot of energy is being wasted in the flour manufacturing plant. The total cost of energy in the plant for the period (2015) of audit is N 878,472,000. The energy cost per kg of flour produced is N5.26k. According to a report on the manufacturing industry prepared by the U.S. Census Bureau in 2005, energy use in the United State the total energy cost is approximately $4 to $7(N1600 to N2800) per tonne of wheat milled (Gwirtz J. 2008). For Crown Flour Mill, the total energy cost per tonne of wheat milled is N5260 Looking at these Figures; it's easy to see why energy consumption is a major part of mill conversion costs. Table 10 show the total production output of both Mills and the total diesel fuel energy consumed for 2015, which is 167079000kg and 172473336MJ respectively. For the period under study (2015), the total specific energy consumption for diesel fuel 12.412MJ/kg. The high value of diesel fuel specific energy consumption is due to non- availability of natural gas for the gas generator leading to the high usage of diesel fuel. Also, from Table 9, it is shown that the month of January and May has the highest value of specific energy consumption of 1.046MJ/kg. This is due to irregular maintenance of some machines used for manufacturing process.

Of all the machines used in the flour manufacturing process, the roller mill machines in Mill A and B consumes the largest quantity of energy which is 32078200MJ/year and 20808191.27MJ/year respectively. This accounts for 91.8% and 62.6% respectively of energy consumed in the plant. This unit holds the greatest energy saving potential in the plant. The purifier machine in Mill A and the blower standby machine in Mill B are the least consumer of energy among the process machines used in the flour manufacturing process. This accounts for 0.13% and 0.14% of the process operation energy consumption in 2015. Analysis of the energy consumption data showed that large quantity of energy consuming equipment like electric motors that are used to drive most of the machines in the flour Mill Manufacturing Plant were operating below their installed capacity. This is primarily due to the fact that most of the electric motors are old and have been rewound twice or more. Therefore, a notable amount of electrical energy could be saved by developing an overall motor inventory and replacement plan in the plant.

4. CONCLUSION

The energy audit of Crown Flour Mill, Apapa, Lagos State was carried out in order to determine the energy consumption rate and the pattern through which the consumption rate and cost of energy can be minimised. From the findings, the following can be concluded:

- Large quantity of energy consuming equipment like the electric motors that are used to drive most of the machines in the flour Mill Manufacturing Plant were operating below their installed capacity thereby wasting energy. This is primarily due to the fact that most of the electric motors are old and have been rewound twice or more.

- Notable amount of electrical energy could be saved by developing an overall motor inventory and replacement plan in the plant. By so doing, there would be a reduction in energy wastage and production cost.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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