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Energy in Perspective of Sustainable Development in Nigeria

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Abstract Sustainable energy systems are necessary to save the natural resources avoiding environmental impacts which would compromise the development of future generations. Delivering sustainable energy will require an increased efficiency of the generation process including the demand side. This paper reviews the pattern of energy-use in Nigeria and makes a case for the implementation of an energy efficiency policy as a possible strategy to address the nation's energy crisis. The study as well explores the role of industrial energy use in sustainable development in Nigeria and the potential sources to increase energy efficiency in industrial sector. The study showed that the pattern of electrical energy consumption in the industries reviewed was majorly from generating set while power supply from national grid compliment generating set if available; this is 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 industries were identified such as energy loss as a result of aging electric motor, worn out or slack / misaligned machine parts, excessive heating and cooling, use of low efficient lightings etc. The review paper shows that industrial energy efficiency in Nigeria is a readily achievable, cost effective and has potential of reduction in industrial consumption using good energy management practices and energy efficient equipment. This study will be of help to government, industrialists and industrial policy makers.

Keywords: *energy, energy efficiency, sustainable development, energy management, industry*

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1. Introduction

Energy has a major impact on every aspect of our socio-economic life. It plays a vital role in the economic, social and political development of our nation. Inadequate supply of energy restricts socio-economic activities, limits economic growth and adversely affects the quality of life. Improvements in standards of living are manifested in increased food production, increased industrial output, the provision of efficient transportation, adequate shelter, healthcare and other human services. These will require increased energy consumption. Thus, our future energy requirements will continue to grow with increase in living standards, industrialization and a host of other socio-economic factors [1].

As the very basis of development, energy use is closely related to the level of productivity in the industry, commerce, agriculture and even in office activities. Energy consumption per capita is one of the indicators or benchmarks for measuring the standard of living of a people or nation. The unprecedented use of energy which began with the industrial revolution certainly brought about massive increase in productivity and change in lifestyle. Since then energy demand has been in the increase- to produce more products, travel further and faster or to be more comfortable. Physically, energy is defined as the capacity for doing work. The capacities of energy to do work are inherent properties of energy carriers. Although energy cannot be created nor destroyed according to classical thermodynamics, its capacity for doing work can be degraded and destroyed due to system irreversibility in line with the logic of the second law of thermodynamics [2].

Some of the common energy carriers or sources are coal, petroleum, natural gas, nuclear fuels, biomass etc. Of all these, the most widely used energy sources are the hydrocarbon compounds or fossil fuels which account for more than 80% of global primary energy consumption [3]. For instance, fossil energies provide about 67% of the energy needed to produce electricity - a veritable and the most terminal form of energy for transmission and distribution for industrial production processes [4]. Energy usage has become an important concern in the past years and there has been growth awareness and an increase in taking personal responsibilities in preventing environmental pollution by minimizing energy waste. Energy has been the key to economic development worldwide, but in the way it is sourced, produced and used, two major drawbacks have emerged. First, the overall energy system has been very inefficient. And second, major environmental and social problems, both local and global, have been associated with the energy system [5]. Climate change and environmental externalities associated with energy consumption have

become a major international issue. It has been observed that among the various sectors contributing to green house gas (GHG) emissions, industrial sector contribution was significant; thus mitigating GHG emissions from the sector offers one of the best ways of confronting the climate change problem. Energy efficiency is a major key in this regard. An estimated 10-30% reduction can be achieved at little or no cost by improving efficiency of energy use in the industry [6].

Although Nigeria is relatively endowed with abundant fossil fuels and other renewable energy sources, the energy situation in the country is yet to be structured and managed in such a way as to ensure sustainable energy development, most especially in the industrial sector. Nigeria as a nation is passing through a serious energy crisis and it has been even more affected not by a lack of energy resources, but largely due to poor resource and financial management, a crippling dependence on imports particularly second-hand goods built with out-dated, inefficient technology etc [7]. As a nation that has limited technological capacity but sees industrialization as constituting a crucial leverage and pre-condition for meaningful development, Nigeria should be wise enough to manage her scarce energy resources judiciously.

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. Several millions of dollar can be saved in accumulated energy cost when energy is properly managed. Based on this fact, several researchers have reported on the energy consumption, conservation potential and environmental impact of energy use of different industrial process operations both within and outside Nigeria. Nagesha [8] presented the energy consumption pattern in a textile dyeing industrial cluster and environmental implications in terms of emission of GHGs due to energy use. The study identified substantial scope for energy efficiency and analysed energy consumption in the cluster from an economic perspective. All the economic performance indicators adopted in the study seemed to have significant association with energy efficiency in the cluster. Also, it was observed that the small scale industries which are energy efficient performed better on the economic front and experienced 'higher returns to scale'. The study concluded that the firms in the energy intensive product clusters must aim at enhancing their energy efficiency as it leads to multiple benefits and ensures sustainable development in the long run. Fawkes [9] investigated energy efficiency in South African Industry. This study showed that strong incentives exist for energy efficiency improvement in South African industry, in particular, the potential for increasing profit, the need to reduce greenhouse gas (GHG) emissions, the need to maintain economic competitiveness, and the need to delay the cost of new peak-load electricity generation facilities. In their study, Lung et al [10] investigated the impacts that several emerging technologies have had in the U.S food processing industry. This paper assessed the energy efficiency potential for four of these technologies in the U.S. food processing industry. Based on the assessments of these four emerging and newly commercialized technologies, the potential for energy savings in the U.S. food industry is quite strong. In addition, these technologies have yielded important productivity and other benefits. Depending on the available market portions in which these technologies can be implemented, sector-wide energy savings could range from 1572 GJ and 134 million kWh to 2342 GJ and 186 million kWh. In addition, non-energy benefits such as improved product quality, better production and reduced greenhouse gas emissions are likely. Aiyedun et al [11] assessed the energy efficiency in Nigerian Eagle Flour Mills Limited, Ibadan. The study which is limited based on the available years of data collected (1996-2000) analyzed the energy consumption, productivity and efficiency of the company. The results of the study showed that energy is not quite efficiently utilized in this industry 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 was 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. The areas where the industry uses and wastes energy, and where actions for energy conservation can be implemented were identified.

Aderemi, et al [12] 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 study revealed 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. 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 lack of training and retraining of staff, power factor of electrical equipment, and equipment age, among others. In their study, Noah et al [13] carried out a comprehensive energy audit of Vitamalt Nigeria Plc, Agbara using portable thermal and electrical instruments with the objective of studying the pattern of energy consumption and identifying the possibilities of saving energy in the plant. A five year (2000-2004) data on energy consumption of Vitamalt Nig. Plc was collected and analysed. The study showed that the Normalized performance indicator (NPI) calculated over the span of five years gave an average of 1.2 GJ/m^2 indicating a fair range in energy performance level classification (1.0 - 1.2) while significant savings and improvement in energy usage is achievable. The authors concluded that maximizing efficiency of existing system, optimizing energy input requirement and significant capital

investment in procuring new energy conserving equipment must be made for the energy performance level to fall into a good range classification (less than 0.8).

The increasing role of energy efficiency as a catalyst for sustainable industrial development is realism in the industrialized countries of the world. In Nigeria the story is different at the moment as the huge benefits derivable from adoption of energy efficiency and conservation measures by industries remain largely untapped due largely to lack of awareness of the economic and social benefits of energy efficiency measures. This, in addition to high incidence of power outages resulting to large scale use of own power generation and lack of investment capital have given rise to high specific energy content of goods produced by industries in Nigeria. The cumulative effect is loss of competitive edge in the global market by these industries and low after- tax returns. This constitutes a major disincentive to investment and sustainable industrial growth. As a matter of utmost importance, industries in Nigeria should take advantage of opportunities in low level, low risk but high worth energy efficient measures that reduces the bottom line of any business enterprise. In so doing, a lead time will be created to pursue high-tech driven production processes that will find support at maturity in an already established energy efficient culture.

As earlier presented of the previous works on energy efficiency in Nigerian industries, none of these researchers discussed possible ways of achieving sustainable development in Nigeria in perspective of effective utilization of energy in manufacturing industries in the country. Therefore, the prime objectives of this paper are (i) to review energy consumption pattern in Nigeria (ii) to explore the potential sources to increase energy efficiency in industrial sector in Nigeria and (iii) to explore the role of industrial energy use in achieving sustainable development in Nigeria.

2. Energy Situation in Nigeria

Nigeria has an abundant supply of natural energy sources, both fossil and renewable. Energy plays a double role in Nigeria's economy: as an input into all economic activities and as the mainstay of Nigeria's foreign exchange earnings through the export of crude oil and, more recently, from increasing natural gas exports. Nigeria's economy is heavily dependent on the oil sector and now on gas too, since both together account for 90-95% of export revenues, over 90% of foreign exchange earnings and nearly 80% of government revenues. The majority of Nigeria's exports of crude are destined for markets in the United States and Western Europe with Asia becoming an increasingly important market of late.

The National energy is at present almost entirely dependent on fossil fuels and firewood which are depleting fast. According to Chendo [14], recent estimates indicated that the reserve for crude oil stood at about 23 billion barrels in 1998, natural gas 4293 billion m^3 at the beginning of 1999, made up of 53% associated gas and 47% non associated gas. Coal and lignite stood at 2.7 billion tones, Tar sands at 31 billion barrels of oil equivalent and large-scale hydropower at 10,000 MW. Table 1 and Table 2 show various conventional and non-conventional energy sources and their estimated reserves in Nigeria [15].

Table 1. Nigeria's conventional energy resources

Resources	Reserve	Resources in Energy units (billion tonnes)	%Total conventional energy
Crude oil	23 billion barrels	3.128	21.0
Natural gas	4293 billion m^3	3.679	24.8
Coal and lignite	2.7 billion tonnes	1.882	12.7
Tar sands	31 billion barrels of Oil equivalent	4.216	28.4
Hydropower	10, 000MW	1.954(100yrs)	13.1
Total	Conventional/Commercial Energy resources	14.859	100%

Source: Ref [15]

Table 2. Nigeria's non conventional energy resources

Resources	Reserves	Reserves (billion tonnes)
Fuel wood	43.3 million tonnes	1.6645 (over 100 years)
Animal wastes		
And crop residue	144 million tonnes	3.024 (over 100 years)
Small scale hydropower	734.2 MW	0.143 (over 100 years)
Solar radiation	1.0 kWm^{-2} Land area (peak)	-
Wind	2.0-4.0 ms^{-1}	-

Source: Ref. [15]

The current energy supply mix in the country is characterised by Figure 1. This further confirms the fact that presently, renewable-energy use in the country is split essentially between hydroelectricity and traditional fuel wood [16].

From the energy point of view, the Nigeria economy can be disaggregated into industry, transport, commercial, household and agricultural sectors. However, the household sector presently dominated energy consumption in Nigeria. This makes it the most important energy sector

of the Nigeria economy [17]. Figure 2 shows sectoral distribution of National Final Energy Consumption.

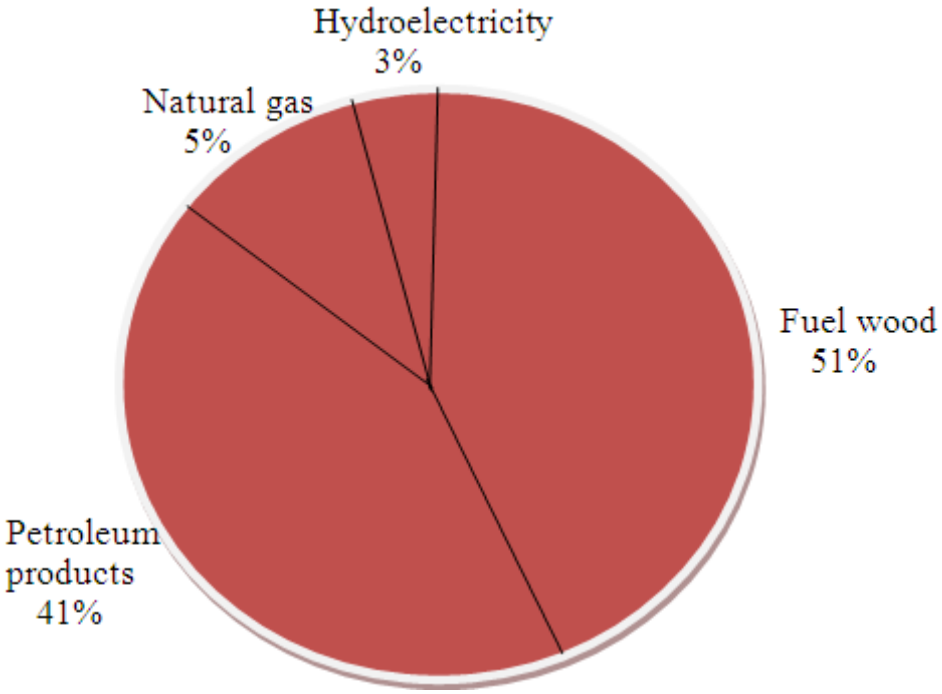

Figure 1. Typical energy supply mix in Nigeria (*Source: Ref. [16]*)

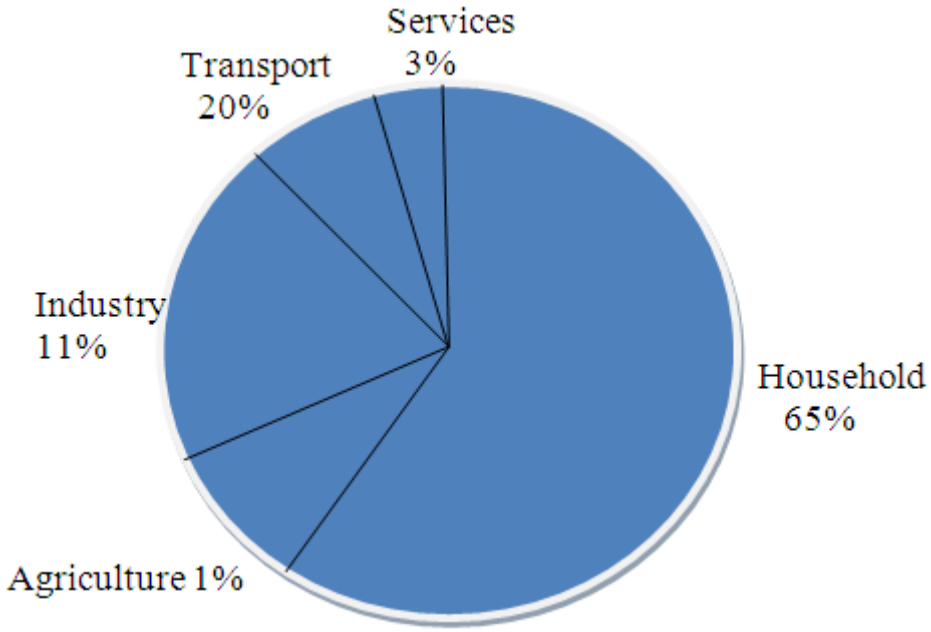

Figure 2. Sectoral distribution of national final energy consumption (PJ) (*Source: Ref. [17]*)

2.1. Energy Consumption Pattern in Nigeria from the Pre Colonial Till Date

The forms of energy consumed in Nigeria have increasingly diversified with innovations in science and technology. In the earliest times, like everywhere else in the primitive world, energy was consumed in the primary renewable form, essentially as biomass in the form of wood fuel and solar energy. Later, at the turn of the present century, primary non-renewable energy forms were introduced from fossil fuels. Only coal was used initially, but later, petroleum products and natural gas were included. These primary forms, which were used mainly for transportation, dominated the energy scene for several years until the principal secondary form, electricity, was introduced.

2.1.1. Coal Production and Consumption

Coal was the first fossil fuel to be discovered and used in Nigeria. Oil was discovered about 47 years after discovery of coal [18]. Coal production in Nigeria started in 1916 with an output of 24,500 tonnes for that year. Production rose to a peak of 905,000 tonnes in the 1958/59 year with a contribution of over 70% to commercial quantities in 1958 and the conversion of

railway engines from coal to diesel, production of coal fell from the beginning of the sixties of only 52,700 tonnes in 1983 [19].

During the civil war years of 1967-1969, production stood at only 20,400-35,000 t. This rose to 323,000 t in 1972 and progressively declined to 118,000 t in 1980. The estimated cumulative production between 1916 and 1980 is about 25.3 million metric tonnes. In 1980 coal contributed less than 1% to commercial energy consumption in the country as compared to 70% for oil, 25% for natural gas and about 5% for electricity.

Over 95% of the Nigerian coal production has been consumed locally, chiefly for railway transportation, electricity production, and industrial heating in cement production lines. Between 1952 and 1958, coal consumption by the Nigerian Railway Corporation accounted for about 60% of the overall consumption. Due to its diesel conversion programme, commenced in 1966, its share of coal consumption fell progressively to <30% in 1966, and to an insignificant level in 1986. The other major consumer, the National Electric Power Authority, NEPA (now the Power Holding Company of Nigeria Plc, PHCN), had about a 16-30% share of the total consumption between 1952 and 1966. As a result of the civil war, its sole coal fired electricity generating station was put into disuse. Consequently, its coal consumption has been insignificant since 1970. The cumulative effect of the decline in demand by the two major consumers, together with the ease and cost-effectiveness associated with the use of other energy sources, resulted in the edging out of coal in the national energy scheme [20].

2.1.2. Petroleum Production and Consumption

Petroleum exploration in Nigeria witnessed steady growth over the past few years. Proven recoverable reserves of crude oil amount to about 1.48×10^6 billion tonnes, with commercial production commencing in 1958. The production then was only 3.1 million metric tonnes, but rapidly increasing market demand forced this to rise to 20.3 million tonnes in 1960, 54.2 million tonnes in 1970, and 104.1 million tonnes in 1980. The observed increases in production have been determined by external market forces, rather than increased local demand. The latter rose from only 1.3 million tonnes in 1970 to barely 6.5 million tonnes / year in 1980. The average domestic consumption to the total production standing at an average value of 3% within the period. Thus, some 97% of the total production is exported, usually as crude oil. The local consumption of petroleum products is supplied from three refineries with a total combined capacity of about 13.5 million tonnes/year since 1980. Supply for the petroleum products up till 1980 was supplemented by imports, while 30% of the output of residual oil was exported. Based on various oil prospects already identified especially in the deepwater terrain and the current development efforts, it is projected that proven reserves will reach about 40 billion barrels by year 2020 and potentially 68 billion barrels by year 2030. Oil production in the country also increased steadily over the years; however, the rate of increase is dependent on economic and geopolitics in both producing and consuming countries. Nigeria's current production capacity is about 2.4 million barrels per day even though actual production is averaging around 2.4 million barrels per day partly due to the problems in the Niger Delta and OPEC production restriction. Average daily production is projected to increase to 4.0 million barrels per day by 2010 and potentially to over 5.0 million per day in year 2030 [21]. The consumption of petroleum products stood between 80 and 90% of the total commercial energy consumption over the 13 yr from 1971 to 1984. The growth rate over the period averaged about 18%, with gasoline 22%, kerosene 17% and diesel 16%. Gasoline and gas oils are mainly used for transport (77%), household uses (12%) and industrial/commercia1 operations (11%). Half of the household consumption was used for operating standby electricity generators.

2.1.3. Production and Consumption of Natural Gas

The Nigerian reserves of natural gas are estimated at 4.67×10^{12} m^3 at a mean specific volume of 1.56×10^{-3} m^3/kg, a mean gauge pressure of about 12 bar and a calorific value of 35 MJ/m^3 [22]. The current production rate stands at about 1.8×10^{10} m^3/yr, usually as associated gas. About 8.5 m^3 of gas can be expected per barrel of crude petroleum. Since the infrastructure for gas utilization is underdeveloped in Nigeria, as high as 75% of the gas produced was being flared in the past. However, gas flaring was reduced to about 36% as a result of strident efforts by the Government to monetize natural gas. Domestic utilization of Natural gas is mainly for power generation which accounted for over 80% while the remaining are in the industrial sector and very negligible in the household sector. Given the current reserves and rate of exploitation, the expected life-span of Nigerian crude oil is about 44 years, based on about 2mb/d production, while that for natural gas is about 88 years, based on the 2005 production rate of 5.84 bscf/day [20].

2.1.4. Production and Consumption of Wood Fuel

Wood fuel contributed about 5% of the fuel consumption of the Electricity Corporation of Nigeria (Now Power Holding Company Nigeria (PHCN)) in 1952/1953, but this decreased gradually to zero by 1960 [23]. Small quantities were also used for rail transport during the same period. The most significant use of fuel wood, however, is for domestic cooking and baking and heating in small-scale industries such as bakeries and brickworks. Presently, the largest sources of fuel wood are communal bushes and private farmlands, from whence fire wood is fetched freely or at a small fee. Between 1961 and 1973, the fuel wood consumption increased by 37% from 41.5 million m^3 in round wood equivalent to 56.8 million m^3 [20]. The 1973 consumption amounted to about 9.1×10^{11} MJ, or an equivalent of 12.1 million tonnes of oil [14]. The projected consumption for 1985 and 2000 are, respectively, 17.8 and 23.6 million tonnes of oil equivalent.

2.1.5. Electricity Production and Consumption

Electricity generation, distribution and consumption became noticeable in Nigeria in the 1930s. By 1961, the total installed capacity was about 185 MW, which increased to 805 MW by 1970 and 2800 MW by 1983 [24]. Small generating units of < 16 MW accounted for about 82% of the total installed capacity in 1965, but production is now heavily dominated by large hydroelectric schemes and gas or oil fired stations. The

lone coal fired steam turbine at Oji has a capacity of 30 MW, but has not been reactivated after the 1967-1970 civil war. In spite of the high installed capacity, the average power is only 1400 MW, while average daily production is 1200 MW with typical availability of about 40% of the installed capacity between 1974 and 1984.

Figure 3 shows total electricity consumption in MWh and the various sectoral consumptions from 1979 to 2007. Public sector electricity utilization by the industrial sector has been fairly static because of the unreliability nature of the public electric supply system in the country. Thus, many companies had resolved in providing their own power generating sets for more reliable self generation of electricity leading to high costs of their products and services [25]. Okafor [14] observed that power distribution to the industrial sector in Nigeria also remains abysmally irregular. The effect of irregular power on the cost of production by manufacturing industries was assessed by Adebayo and Alake [26]. The study observed that cost of operating on self power generating sets is 50 times cost of operating on power supply from national grid by PHCN.

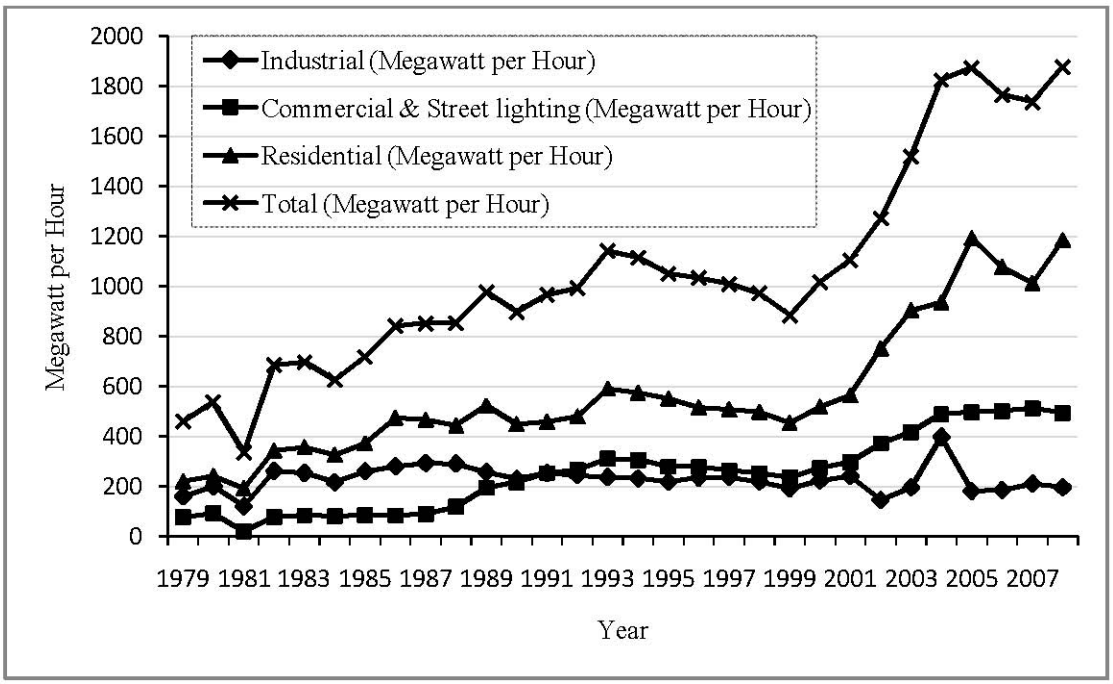

Figure 3. Electricity consumption pattern in Nigeria (Source: Ref. 14)

3. Overview of Industrial Sector Trends

The industrial sector represents more than one third of both global primary energy use and energy-related carbon dioxide emissions [27]. In developing countries, the portion of the energy supply consumed by the industrial sector is frequently in excess of 50% and can create tension between economic development goals and a constrained energy supply.

The industrial sector uses 160 exajoules (EJ) of global primary energy, which is about 37% of total global energy use. Primary energy includes upstream energy loses from electricity, heat, petroleum and coal products production. The industrial sector is extremely diverse and includes a wide range of activities. This sector is particularly energy intensive, as it requires energy to extract natural resources, convert them into raw materials, and manufacture finished products. The industrial sector can be broadly defined as consisting of energy-intensive industries (e.g., iron and steel, chemicals, petroleum refining, cement, aluminium, pulp and paper) and light industries (e.g., food processing, textiles, wood products, printing and publishing, metal processing) [28].

The aggregate energy use depends on technology and resource availability, but also on the structure of the industrial sector. The share of energy-intensive industry in the total output is a key determinant of the level of energy use.

3.1. Energy Use Efficiency in Industry

Energy efficiency is a term used in different ways, depending on the context and possibly on the person using it. But it is more commonly understood to mean the utilisation of energy in the most cost effective manner to carry out a manufacturing process or provide a service whereby energy waste is minimised and the overall consumption of primary energy resources is reduced. In other words, energy efficient practices or systems will seek to use less energy while conducting any energy-dependent activity; and at the same time, the corresponding (negative) environmental impacts of energy consumption are minimised. According to The Aspen Institute Centre for Business Education [29], energy efficiency is defined as the ability to generate the same economic output with less energy input.

Industrial energy efficiency or conversely, energy intensity, defined as the amount of energy used to produce one unit of a commodity is determined by the type of processes used to produce the commodity, the vintage of the equipment used, and the efficiency of production, including operating conditions [30]. Energy intensity varies between products, industrial facilities, and countries depending upon these factors. The objective of an energy

efficient industrial system is analogous to "just in time" manufacturing—to provide the appropriate level of service needed to support the production process, to have a backup plan to address emergencies, and to keep the entire system well-maintained and well-matched to production needs over time.

Energy efficiency is rising toward the top of many national agendas for a number of compelling reasons that are economic, environmental and intergovernmental in nature. As many industries are energy-intensive, this is resulting in new impetus to industrial energy efficiency policies. The economic reasons are quite clear. Most important has been the rise in energy prices from 2005-2006 and their likely continuation at a high level. Increasing concerns over energy security (reliability of supply) are a second factor. Energy supply in many countries increasingly depends on imported oil and gas, and supply is being constrained by geopolitical events while global economic growth is resulting in greater energy demand. Additionally, in many developing countries energy efficiency is also a way to alleviate the investment costs for expanding energy supply infrastructure in the face of tight fiscal constraints [31].

Despite the potential, policy makers frequently overlook the opportunities presented by industrial energy efficiency to have a significant impact on climate change mitigation, security of energy supply, and sustainability. The common perception holds that energy efficiency of the industrial sector is too complex to be addressed through public policy and, further, that industrial facilities will achieve energy efficiency through the competitive pressures of the marketplace alone. Neither premise is supported by the evidence from countries that have implemented industrial energy efficiency programs. The opportunities for improving the efficiency of industrial facilities are substantial, on the order of 20-30% [32], even in markets with mature industries that are relatively open to competition.

Industrial energy efficiency is dependent on operational practices, which change in response to variations in production volumes and product types. Due to this dependence, industrial energy efficiency cannot be fully realized through policies and programs that focus solely on equipment components or specific technologies. Companies that actively manage their energy use seek out opportunities to upgrade the efficiency of equipment and processes because they have an organizational context that supports doing this wherever cost effective, while companies without energy management policies do not. Providing technology-based financial incentives in the absence of energy management will not result in significant market shifts *because there is no organizational context* to respond to and integrate the opportunity into ongoing business practice [30].

There are many benefits of increased energy efficiency. These can broadly be categorised into financial/economic, environmental and social benefits. The relative importance of each of these benefits depends on the actual situation in a given country or area, including for example the prices of different types of energy, the cost of energy efficiency measures and equipment, the tax regime and the current levels of energy efficiency already being achieved [33]. For private companies, the most important benefits of higher energy efficiency will be linked to the financial benefits of lower costs for running the business. This applies to typical manufacturing companies as well as to energy suppliers such as electricity generating plants and oil refineries. The drivers for improving industrial energy efficiency include the desire to reduce overall costs of production in order to maintain competitiveness, reducing vulnerability to rapidly increasing energy prices and price spikes, responding to regulatory requirements for cleaner production (including air quality, solid waste, and greenhouse gas emissions), and meeting consumer demand for greener, more environmentally-friendly products [30].

Notably, while energy-use is increasing in many developing countries, especially, Nigeria the imperatives to enhance energy efficiency in industries have received little attention. This gives rise to the question: if energy efficiency pays, why is it not happening in developing countries? Many studies have been carried out on energy utilization in Nigerian industries. The results have shown opportunities for energy efficiency in industrial sector.

3.2. Opportunities for Industrial Energy Efficiency in Nigeria

In Nigeria, energy savings opportunities in the industrial sub-sector of the economy have remained a matter for speculation over the years due to uncoordinated efforts at addressing issues relating to energy efficiency and management. It is in the bid to create necessary awareness on the huge potentials for energy savings in the sector that Energy Commission of Nigeria in collaboration with United Nations Industrial Development Organization (UNIDO) and other stakeholders have for some time now engaged themselves in industrial energy efficiency programs in Nigeria.

Strictly speaking, two forms of energy carriers are commonly used in the industry: electricity and heat. However, among all the energy forms, electricity is the most widely deployed in the industry for the transformation of raw materials into the desired end products. Electricity consumption in the industry is usually for lighting and motor power-drives of various kinds of equipment, such as pumps, fans, compressors, blowers, conveyors, air conditioners and various machine tools. It is also used in electric furnaces and electrolysis. Improvement in the efficiency of electric motors in particular can result into large energy and cost savings. On the other hand, thermal energy is mostly used in boilers for process steam generation and in kilns such as in cement production [34].

Energy Audits and Surveys are the roadmaps to energy efficiency and conservation measures in the industry. They provide information required to make decisions on which are the most cost-effective measures of energy efficiency program to implement. Answers such as the types of energy use in an industry, how much is being used, the cost, where it is being used, factors affecting consumption, savings potentials and economic assessments are equally met by energy efficiency programs. Investigation carried out in some industries in Nigeria reveals areas of energy conservation (savings) in Nigerian industries.

Below are highlights of walk-through energy audits of some industries in Nigeria.

3.2.1. A Foundry Industry

Walk-through energy audit carried out in this industry shows that there are opportunities for energy savings in the industry. For instance the total current measured is above the rated value for the mains breaker, leading to unacceptable overheating and frequent tripping of the breaker which is now superficially overcome by the installation of a big standing fan to dissipate the generated heat. This is a source of energy waste and can be avoided replacement of the mains breaker especially due to the fact that the contacts may melt completely and results into shutdown and loss of production man-hours. Furthermore based on the measured TDS value of the high frequency induction furnace cooling water system, it is inferred that the ion exchange resin has expired and are therefore due for recharging or replacement to avoid scale formation and rust along the piping network.

3.2.2. Plastic Industry:

In this industry it was observed that energy savings potentials in the plastic company include: Repair of badly damaged insulation, Elimination of fuel, gas, oil and water leaks, Reduction in excessive heating and cooling, Cleaning of dirty surfaces of heat exchangers, motors and lamps, Prompt replacement of worn out belts, Greater use of diffused light, Replacement of the large number of incandescent light bulbs with energy efficient CFLs.

3.2.3. Bottling Company

In this industry, it was observed that the electricity supply is 100% from 3No 800kVA diesel generators while thermal energy for the boiler is from low pour fuel oil (LPFO). Two, out of the three diesel generators are run at a time (24hrs/day) and the other stays on standby. To say the least, this scenario is replicate of most industries in Nigeria which is due to poor electricity supply situation in the country. In terms of energy efficiency, the compounding wastes along the energy supply line are better imagined.

The scenario in the bottling company in relation to energy efficiency is that, a 10 bar, 2 metric ton per hour capacity, low pour fuel oil fired steam boiler, produces steam at a pressure of 4-5 bar (about 140°C-150°C) use in bottle washing that requires hot water at temperature of about 80°C-90°C. It was observed that the steam produced at a high temperature of about 140°C has to be throttled to reduce the temperature to the required level for bottle washing. Ironically the runoff water from the final washing stage comes out at a temperature of 60-70°C and is emptied into the drain. While this practice is considered proper from point of view of avoidance of contamination, it is suggested that a low pressure steam boiler operated at 2 bars can meet the steam requirement and thus save thermal energy.

Furthermore in the compressed air unit, the water-cooled single stage compressor delivers at a temperature of about 80°C while the cooling water comes off at 60°C and is again let off the drain. Opportunity for energy efficiency here is that the heat of the air compression can be recovered to heat the boiler feed water and this may result to about 5% energy savings.

3.2.4. Beer Manufacturing Company:

The investigation reveals the following areas of energy savings opportunities: In the De-aerator – copious amount of steam loss from the deaerator by deliberate action of operators; Steam line leakages from loose joints and holes along the piping network; The Wort Kettle- Loss of latent heat in the evaporation of water from the kettle; Exposed steam lines- Radiation loss from un-insulated parts; Boiler fuel-not sufficiently atomized for efficient combustion; Boiler oversized and operates on part load most of the time; Cooling Tower- treated water allowed to over flow and thick ice formation along NH_3 pipeline; Brine motor pump-Use of constant speed motor drive which run continuously even at no load; Large quantity of water waste at the bottle cleaning section; Boiler TDS not monitored, feed water make up not measured and condensate not recovered; Generator frequency low at 47Hz and power factor low at times.

3.2.5. Chemical Industry

In this industry the source of electricity used in this factory includes: a 1,250KVA gas generator that runs for 24hrs except when it is under maintenance, a 1000KVA diesel generator is used to support the main generator during repairs, also a 153KVA diesel generator used to run the factory when there are no activities. A 500KVA transformer connected to PHCN to generate electricity. Walk-through energy audit carried out in this industry reveals the following areas of energy savings opportunities: Replacement of high capacity generators with smaller capacity generator for load shedding as this will minimize energy wastage. A lot of energy is wasted as the high capacity generators are not fully utilized; Replacement of the large number of high pressure sodium bulbs with energy efficient CFLs; Replacement (especially large) standard electric motors with high efficiency types (especially in the mill-hopper section); Installation heat-reclamation equipment – economizers and air heaters for flue gas and heat exchangers / heat pumps for boiler blow down. Replacement of high capacity generators with smaller capacity generator for load shedding as this will minimize energy wastage.

3.2.6. Food Industry

Study on pattern of electrical energy consumption from 210 selected micro and small-scale food and beverage companies in Nigeria was carried out by Aderemi et al [12]. 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.

3.3. Industrial Energy Efficiency Programme and its Influence on Economy

Industrial energy efficiency has emerged as one of the key issues in ensuring that the per capita income of citizens of a country is improved upon [35]. For example, in 2002, India's total primary energy consumption amounted to 538 million tonnes of oil equivalent. The industrial sector used about 40% of total energy in the country. Six energy-intensive industrial sub-sectors—Aluminum, Fertilizer, Iron and Steel, Cement, Pulp and Paper and Chloral–alkali—consumed 60% of industrial energy. The expenditure in energy among the total production costs in India's industrial sector is generally very high, accounting for 15% in textiles, 25% in pulp and paper, and 40% in glass, ceramics and cement. The Indian Government is therefore interested in developing better policies and measures to supply energy more efficiently and save energy effectively in the industrial sector. A number of energy efficiency policies and measures have been developed over the past 25 years. These include (i) disclosing companies' particulars on energy efficiency; (ii) accelerated depreciation for energy efficiency and pollution control equipment; (iii) setting up the Energy Management Centre under the Ministry of Energy; (iv) the deregulation to promote industrial competitiveness; (v) energy price reforms to guide energy efficiency initiatives and to encourage international competitiveness; and (vi) enforcement of the Energy Conservation Act and the Electricity Act. From the experience of India, Nigeria stands a lot to gain from energy efficient programmes which would make cost of production to reduce. This programme is very low and new to many manufacturing industries in Nigeria as a result of the following:

- Over 40% of energy used is wasted in old, ageing and obsolete industrial equipment which are most of the times very much inefficient.
- 25% saving potential from good house-keeping measures.
- Retrofitting in industries would be able to save about 35% of energy currently in use.

Since this sector spends close to 30% of total cost of production then such an amount can be spent on retrofitting and employment of energy saving programme such as lighting system; using compact fluorescent lamps (cfls), energy-efficient motors, improved steam boilers, etc [36].

3.4. Energy Use Efficiency and Sustainable Development

Sustainable energy can be defined as energy which provides affordable, accessible and reliable energy services that meet economic, social and environmental needs within the overall developmental context of society, while recognising equitable distribution in meeting those needs [5]. In practice, sustainable energy has meant different things to different people. Some think of it as the energy related to renewable energy and energy efficiency. Some include natural gas under the heading of sustainable energy because of its more favourable environmental quality. Whatever approach is used, sustainable energy always implies a broad context which covers resource endowment, existing energy infrastructure, and development needs.

Sustainable energy will, however, require new approaches in the mobilisation of energy resources for development. This would involve: shifts to renewable energy sources; development and wide dissemination of sustainable and renewable energy technologies; energy efficiency and conservation; and technological developments that allow the use of fossil fuels in a cleaner way [37].

Sustainable development is defined as development that meets the present needs and goals of the population without compromising the ability of future generations to meet theirs.

Energy is related to the multidimensional aspects of sustainable development: the economic social and environmental perspectives. Adequate and affordable energy supplies have been the key to economic development and the transition from subsistence agricultural economies to modern industrial and service-oriented societies. Energy is central to improved social and economic well-being, and is indispensable to most industrial and commercial wealth generation. It is the key to relieving poverty, improving human welfare and raising living standards. But no matter how essential it may be for development, energy is only a means to an end. The end is good health, high living standards, a sustainable economy and a clean environment. No form of energy — coal, solar, nuclear, wind or any other — is good or bad in itself, and each is only valuable in as far as it can deliver this end [38].

The requisite of sustainable development is that the production and use of energy should not endanger the quality of life of current and future generations and should not exceed the carrying capacity of ecosystems. Of all the measures that will contribute to meeting this requisite and/or of challenge of sustainable development and limiting climate change, one obvious solution is to use energy more efficiently. That means consuming less energy to produce goods and services,

Environmental-friendly new behaviours and working methods, coupled with the use of new technologies that offer better energy performance [39]. Energy-use efficiency is the fastest, cheapest, cleanest way to address these challenges. The efficient use of energy and supplies that are reliable, affordable and less-polluting are widely acknowledged as important and even indispensable components of sustainable development [40,41].

3.5. Highlights of Policy Implications from the Study

From the study a number of important policy implications are implicit. These include:

• Electricity from the national grid is heavily subsidised and does not give incentive for energy efficiency investment;

• High energy cost has adversely affected employment situation in the industry. Retrenchment of workers/reduction in number of shifts is always an easier way of reducing cost than other options such as energy efficiency;

• Energy reduction is another substitute for job reduction and both companies and government as well as development partners should be actively engaged in industrial energy efficiency options in developing countries, like Nigeria;

• In some of the companies' plants, many machines are very old and thus do not meet the highest energy efficiency standard;

• In some companies, lots of heat energy are generated as by-products but are not being reused at other parts of the plants but simply thrown away;

• National benchmarks for energy consumption in the various industrial processes are not available;

• Some of the companies expressed the need for external consulting, auditing and advice on energy efficiency opportunities;

• Possibility of joint production of power by companies is there but such independent power generation depends on reliable gas supply and competitive energy prices;

• Need for case studies and concrete measures which can be followed by companies to become more energy efficient. In other words, technological advice on energy efficient options will be very useful;

• The need to help in developing cases for small and medium scale power plants and providing information about industrial energy-use;

• Finance for investment in energy efficiency not readily available either from retained earnings or bank loans due mainly to the financial crisis; and

• Need for incentives or subsidies on investments in energy efficiency. Since companies pay fine for polluting the environment with generators, they should be rewarded for greening the environment with energy efficient machines/processes.

3.6. Benefits of Industrial Energy Efficiency Measures

Benefits generally derivable from industrial energy efficiency measures are highlighted below:

3.6.1. Cost Savings

Energy represents cost; therefore saving energy through efficient use saves production cost. In addition to reducing costs it releases funds for further investment for other purposes. Depending on the type of industry, an estimated 10-25% energy savings are achievable. Replacing old and rewound motors for example by energy efficient motors would result to a considerable savings in terms of energy and running cost which is 8 to 10 times the cost of investment for the same motor. For electric motors the kW savings margin is given by the following relation:

$$\%kW\ savings = \left(New\ Efficiency - Old\ Efficiency\right) / New\ Efficency \times 100$$

3.6.2. Environmental Savings

Improving energy efficiency is one of the most effective means of improving environmental performance. Energy efficiency programs in the industrial sector in Nigeria will provide a source of reducing greenhouse gas emissions under a clean development mechanism scheme as laid out in article 12 of the Kyoto protocol. This is true especially when viewed against the backdrop of the fact that the production and use of energy account for between 50 to 60 % of the greenhouse emissions into the atmosphere1. Energy not used cannot pollute the environment.

3.6.3. Resource Savings

Energy efficiency and conservation measures act as a quicker and cheaper way to save scarce energy and material resources. For instance, in boiler operations, a 3mm diameter hole on a pipe line carrying 7kg/cm^2 steam would waste 32,650 litres of fuel oil per year. A simple housekeeping measure that fixes the hole saves that amount of resources.

3.6.4. Enhances Competitive Edge

A company that produces the same quantity of products with reduced energy input or produces higher quantities of products with the same amount of energy will maintain a competitive edge over a similar company with high energy bills. This simply indicates that more energy-efficient practices can effectively reduce operating cost and enhance competitive edge for a relatively small investment.

3.6.5. Promotes Sustainable Industrial Development

There is evidently no gainsaying that energy efficiency and conservation measures will be a very effective pathway of promoting sustainable development which has been described as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". In a rule of thumb sustainable industrial development can similarly be described as "keeping the industries working today, tomorrow and in the future through a systematic approach to energy efficiency measures that meets the needs of the present without compromising the needs of upcoming generations." Therefore increasing energy availability through rational use is one way to ensure sustainable industrial development in Nigeria.

3.6.6. Promotes Corporate Social Responsibility

Corporate social responsibility is a concept focusing on the business contribution to sustainability. It is a process by which companies manage their relationships with a variety of stakeholders who can have real influence on their license to operate. Energy efficiency measures can therefore provide industries with instruments to deal with new challenges and requirements to meet with global expectations particularly curtailing CO_2 emissions and other pollutants.

3.6.7. Promotes Increased Productivity

Energy efficiency measures leads to increased productivity and reduces industrial hazards and risks to worker health.

4. Conclusion

Energy is an important production factor and therefore should be managed in parallel with land, labour and capital. Energy efficient production process should be seen as a quick and cheaper source of new energy supply

as the cost of providing energy can be several times the cost of saving it. Increasingly energy efficiency is considered to include not only the physical efficiency of the technical equipment and facilities but also the overall economic efficiency of the energy system. Hence the adoption of energy efficiency measures in the industrial subsector in Nigeria will enhance profitability, reduce greenhouse gas emissions, promote sustainable development, and improve corporate social responsibility. The time to begin aggressive campaigns for energy efficiency measures in the Nigeria industrial sub-sector in particular and the whole economy chain in general is long overdue.

Pertinent outcomes from this study are (i) the general level of information in Nigeria on industrial energy efficiency is low; (ii) very few companies have adequate awareness and knowledge about implementing energy efficiency projects; (iii) most companies have never carried out an external energy audit to determine areas where efficiency can be enhanced; (iv) most companies need active policy on identifying and repairing leakages such as air, heat and steam, through a combination of internal and external energy audit; (v) the relative low price of fuel in Nigeria, combined with the high investment costs for machines result in long payback period for investments in energy efficiency; (vi) despite the major problem of energy supply facing the companies, a number of them have no clear information on energy efficiency options; and (vii) finance for investment in energy efficiency not readily available either from retained earnings or bank loans due mainly to the financial crisis.

Energy demands by industries in Nigeria will continue to grow. Presently most of these industries are financially and environmentally unstable. With increasing pressure on available resources due to large population, very low GDP, loss of competitive edge in the global market of goods produced in Nigeria, and a drive to catch up with the rest of the world in improving the standard of living of her citizens by at least 2020, Nigeria cannot afford to waste her energy resources through inefficient industrial production processes. There is therefore an urgent need to promote energy efficiency and management measures for sustainable industrial development in Nigeria.

The key policy challenge is the need to address the subsisting paradox where companies pay fine for polluting the environment with generators but are not rewarded for greening the environment with energy efficient machines/processes. This paper therefore recommends the need for incentives or subsidies on investments in energy efficiency.

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