International Journal of Engineering and Technology Innovation, vol. 5, no. 1, 2015, pp. 56-65

Investigation of Energy Use Pattern and Emission Discharge in Nigeria: A Case Study of South West Zone

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Received 7 May 2014; received in revised form 25 November 2014; accepted 10 September 2014

Abstract

Electricity demand has increased with population growth, industrialization and civilization. Most householders are barely conscious of the conservative measures for available limited supply, while the environmental impact has rarely been taken into cognizance by consumers. The study examines end-users attitude to energy consumption in Nigeria based on four scenarios. Gaseous emissions data obtained from prepaid and post-paid metering systems usage in low-income and high-income housing types were analyzed. Results obtained indicate strong relationship between energy use and emissions with significantly different emission generation. About 38% and 23% reduction in global warming and acidification potential is achieved by a switch to prepaid meters for both income earners. Post-paid low-income earners utilized the highest energy (59.8kW/hr) while the prepaid high-income earners had the minimum (31.1kW/hr). Energy use and greenhouse gas emissions from both earners followed similar trend. Prepaid metering system usage improves energy consumption, thereby offsetting global warming and acidification impacts.

Keywords: greenhouse gas emission, energy use pattern, metering system, electricity consumption

1. Introduction

Energy resource capacity in Nigeria is plenteous. Virtually all energy sources are available in serviceable quantity in the nation if judiciously harnessed. The potential electricity generation from solar, hydropower, biomass (biogas) and wind turbine at 10 and 25m heights in Nigeria is 1850 X 10^3GWh/year [1], 11000MW, 6,800,000m^3/daily [2] and 120 – 791kWh/year [3] respectively. Despite this promising worth, energy generation, distribution and utilization has been the major challenge in the nation. The supply is erratic, insufficient and unevenly distributed in spite of the efforts being undertaken by the government and other bodies concerned to ensure improvement. The available hydro and thermal energy sources have not been optimally exploited and managed to cater for the lingering demand. While other natural promising areas such as abundant solar, geothermal, wind and other available renewable energies are underutilized or untapped [4]. These shortfalls have been

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attributed to a number of factors namely; poor infrastructural maintenance, aged-equipment, low pragmatic governmental intervention in terms of budgetary allocation and implementation, misappropriation of allocated funds and other economic reasons . Other problems as highlighted by [5] include market monopoly, deficient energy mix, poor gas supply, destruction of generation facilities and drought.

The national grid supply rose slightly above 4,000MW [6] with an installed generation capacity of 7876MW [7] in February 2013. Further improvement to the national grid supply was assured by Nigerian Electricity Regulatory Commission (NERC) in subsequent year [8]. Regardless of this welcomed development, the present energy demand and supply in Nigeria is far from being sufficient. Even the seemingly growth recorded in energy generation is hunted by instability due to environmental and societal crises [9]. In order to address this subject, immediate and futuristic electricity demand and supply must be investigated. Reference [10] employed model for the analysis of energy demand (MAED) and model for the energy supply strategy alternatives and their general environmental impact (MESSAGE) for this purpose. The results show that at 11.5% gross domestic product (GDP) growth rate, electricity demand and supply would be 31,240MW and 31,235MW respectively by 2015. In the subsequently five years, this would have increased to 70,760MW and 71,964MW vis-à-vis the unchanged growth rate. However, these projected values were attributed to economic and industrial development [11]. Another divergent view maintained that the determinant factors for present and projected electricity demand values in Nigeria are predominantly income, price of substitute and population increase [12]. In order to meet this herculean task of electricity supply, fossil fuel powered generators that are expensive and not environmentally friendly are used to augment the shortage in supply. Most end-users have spotted this as a cosmetic approach to cushion the effect of epileptic power supply in Nigeria not minding the long term cost, environmental and health implications. Another promising alternative is to consider the conservation of electricity by end-users' lifestyle, as power distribution and supply is envisaged to be more effective when wastage is reduced. Reference [11] considered this as an effective means of energy management resource because of its potency to achieve efficient energy use pattern. The approach is similarly cost effective in terms of emission reduction [13]. Reduction in energy consumption is a welcomed strategy in residential and commercial areas worldwide with the aim of curtailing the growing electricity demand and combating increasing air pollution from power use and generation [14]. Most advanced countries have subscribed to the usage of prepaid billing system as against post-paid type in order to inculcate a conscious reduction in energy wastage that will equally reduce pollution impacts. This employs the principle of cut-back in electricity demand. In Nigeria, introduction of the prepaid meter as against the post-paid meter is a recent intervention primarily adopted to offset unnecessary overhead and outrageous bills served to post-paid meter users. It is worthy of note that emission rate for energy use pattern under both metering systems has not been comparatively quantified, although studies have been widely carried out by investigators in both developed and developing countries such as USA, Syria, Brazil, Sweden, Namibia and Kuwait on the effects of efficient use of energy as a means of limiting environmental pollution [11]. Other nations like China [18], UAE [20], UK [21] etc. have as well ventured into similar project. It is deemed that the prepaid metering system should stand the chance of electricity conservation by end-users who have a unique energy use pattern and thereby reducing environmental pollution.

Global warming and acidification are some of the pollution offshoots attributed to extensive fossil fuels exploitation. The former is as a result of carbon (iv) oxide released from mainly anthropogenic activities. Literatures have further elucidated it cause to a drastic reduction in polar ice cap leading to increased level of earth surface temperature with elevated chlorofluorocarbons level [17]. This is part of the root cause of the recent world's pronounced flooding crises and Nigeria has had her fair share of flooding due to consequence of global warming coupled with environmental mismanagement [19] While acidification, often referred to as acid rain, is another environmental degrading phenomenon attributed to pronounced quantity of sulphur (iv) oxide and oxides of nitrogen in the atmosphere. Vulnerable surface and ground waters become acidified due to

trans-boundary atmospheric contamination that causes harm to human, flora and fauna [18]. This interference with environmental integrity has over the years culminated into health challenges, metal rust, building damage, marble and limestone worn out [18]. This therefore has birthed among others the search for a systematic approach in energy usage pattern that mitigates environmental degradation. Other proven and effective approach is the market based method [18].

For the purpose of this study, the energy use pattern within consumers of electricity was classified into four namely; prepaid low income earners (PLIE), post-paid low income earners (POLIE), post-paid high income earner (POHIE) and prepaid high income earner (PHIE). This classification was based on the income level of consumers and the metering system available in the given location. Income level of householders or consumers has been strongly linked with household energy use viz-a-vis associated emissions [16]. The electricity sector of the nation was decentralized as a result of the privatization of the Power Holding Company of Nigeria (PHCN) into power generation, distribution and marketing arms. Consequently, a form of conservation at one end is most likely to lead to a chain reaction along the ladder of production. For instance, a reduction in energy wastage at the marketing level (end-user) will have a chain effect on energy distribution and hence making power generation effective. It is therefore imperative to ensure that the populace general attitude and lifestyle is tailored towards ensuring a reduction in the rate of environmental degradation and pollution. Individual and authorities concerned in Nigeria should make conscious efforts to protect the environment if it is to achieve environmental sustainability, which is one of the millennium development goals (MDGs) pursued by the government.

This study assesses the effects of the energy use pattern of electricity consumers in south western part of Nigeria by means of the life cycle assessment method. Life cycle assessment is a proven and widely used instrument for improved environmental management. A number of researches have been understudied using this evaluator among them is [20]. The tool involves four basic stages which are the definition of scope and objectives of the study, collection of lifecycle inventory, estimation of effects and assessment of these effects.

The objective of the research was to investigate the emission generation from the energy use with respect to prepaid and post-paid metering system in different households (low and high income earners) with focus on acidification and global warming potentials.

2. Study Area

Nigeria is one of the countries in West Africa grouped into six geo-political zones. One of these zones is the south western zone. South western Nigeria lies between longitude 30^0 and 7^0 E and latitude 40 and 9^0 N and comprises of six provinces or states. The population density, land mass, human population and average growth rate of south western Nigeria as at 2006 National Population Census organized by the Federal Government of Nigeria was 4053.5 persons per square kilometer, 78505.17 square kilometers, 27,713,450 and 3.21% in that order.

Recent power reforms in the country has seen the power sector of the country which was formerly solely run by the Power Holding Company of Nigeria (PHCN) being divided into the Generation companies (GENCOs) and Power Distribution Companies (DISCOs). The administration of power generation is solely handled by the GENCOs while billing systems are handled by DISCOs. Power billing system in south western Nigeria is shared between three main Power Distribution Companies (DISCOs) which are the Ikeja, Ibadan and Benin DISCOs. The typical electricity bill in the country is made up of two parts which are namely the Fixed Monthly Charge (FMC) and the Monthly Energy Charge (MEC). The FMC component of the bill is meant to take care of installation maintenance while the MEC is the part of the bill associated with energy usage of the

consumer. Consumers are also charged in different categories namely Industrial, Residential, Commercial, Special and Street Lighting. The Nigerian Electricity Regulatory Commission (NERC) recently put into operation a Multi-Year Tariff Order-2 (MYTO-2) for both FMC and MEC which covers a five-year period as shown in Table 1 and 2 [22]. A critical look shows that the MYTO-2 shows that the aggregate cost of energy is constantly increasing which is in response to inflation and other factors. This singular factor is expected to have an effect of consumer behavior as dictated by classical economic theories.

Table 1: Multi-Year Tariff Order-2 Residential Energy Charge for the different DISCOs

DISCO	2012-2013 (Naira/kWh)	2013-2014 (Naira/kWh)	2014-2015 (Naira/kWh)	2015-2016 (Naira/kWh)	2016-2017 (Naira/kWh)
Ikeja	12.45	12.83	13.21	13.61	14.02
Ibadan	12.3	12.91	13.56	14.23	14.95
Benin	11.37	11.94	11.94	12.54	13.16

Table 2: Monthly Multi-Year Tariff Order-2 Residential Fixed Energy Charge for the different DISCOs

DISCO	2012-2013 (Naira)	2013-2014 (Naira)	2014-2015 (Naira)	2015-2016 (Naira)	2016-2017 (Naira)
Ikeja	500	750	895	1067	1273
Ibadan	500	500	625	781	976
Benin	500	750	1500	1800	1800

Source: [22]

3. Methodology

The study examines energy usage in domestic homes within south western part of Nigeria to determine whether the metering system affects the energy use pattern in the study area. This will possibly have an effect on emission generated from these households. The lifecycle assessment (LCA) method requires that references should be made to the functional unit of a study. The domestic homes as energy consumption units have been defined as the functional unit for this research, though the nation is considered as low medium income earners. This is according to World Bank income classification vis-a-vis income group [23]. The nation is equally categorized as developing country with respect to [24] view on International Monetary Fund classification based on level of development. Studies have shown that energy use pattern and carbon footprint is linked with income level of householders [25]. Energy consumers were classified in relation to the earning levels as low and high. The basis for this was to investigate the existence of any disparity in energy usage between both classes. Income earners below ₦48, 000.00 per month ($290) were classified as low income earners within the Metropolis with earners above this range considered as high income irrespective of their location with thoughtfulness given to the type of building (Personal Interview). Although this value is lower than MDGs classification, the concept of choice was relative to standard of living in this region (south western Nigeria). Unbiased random selections of houses were done for the four classifications, which are prepaid low income earners (PLIE), post-paid low income earners (POLIE), post-paid high income earner (POHIE) and prepaid high income earner (PHIE). These four classes (PLIE, POLIE, POHIE and PHIE) served as the functional units of the LCA study. A sample size of 29 households consisting of functional units of 9 PLIE, 6 POLIE, 10 POHIE and 4 PHIE were randomly selected and energy consumption was measured as stated above. The choice of functional unit distribution in the sample space was made based on

the approximate consumer class distribution in the population. An Inventory was obtained from post-paid analogue meters installed in high and low income earning households as well as digital prepaid meters installed also in low and high income earning homes. The readings were taken at an average weekly power supply rate of 105 hours per week for the four power consumption units.

Readings on the respective meters were obtained at specific intervals over a period of three weeks and the average power consumption (P_{avg}) per household calculated using the formula given below:

$$\mathbf{P_{AVG}} = \frac{\mathbf{(R_3-R_2)+(R_2-R_1)+(R_1-R_0)}}{\mathbf{3}} \quad (1)$$

where, R_0 = Meter reading at the beginning of the process
R_1 = Meter reading after the first week
R_2 = Meter reading after the second week
R_3 = Meter reading after the third week

The Power consumption per functional unit (P_{CFU}) was calculated by finding the mean value of the P_{avg} for each of the functional units as given below

$$\mathbf{P_{CFU}} = \frac{\mathbf{\Sigma P_{avg}}}{\mathrm{n}} \quad (2)$$

where n = number of households considered for each functional unit

Inventory was processed with the aid of a formatted Microsoft Excel emission calculator adapted for Nigeria to obtain the global warming potential (GWP) in terms of CO_2 equivalent for CO_2, CH_4 and N_2O per functional unit. The acidification potential (AP) was also computed using the same tool in terms of SO_2 equivalent for NO_x and SO_x per functional unit.

Emission factors for electricity listed in Table 3 were based on the power mix in the national grid which comprises 22.4% hydropower and 77.6% thermal power (using natural gas as fuel) as previously reported by [21]. Global warming potentials of CO_2=1, CH_4=23 and N_2O=298 were used in the computation of values as recommended by [26]

Table 3: Emission factors for electricity [21]

Emissions	Emission Factors (kg /kWh)
CO_2	1.42E-01
CH_4	2.71E-05
N_2O	2.65E-06
SO_2	7.21E-07
NO_x	1.18E-04

4. Results and Discussions

Results obtained from the 29 randomly selected households show that 34% were postpaid high income, 14% were prepaid

high income, 42% were postpaid low income households and 10% were prepaid low income households (Figure 1). These deviations were catered for by the respective mean values as shown in Tables 4 and 5. Computation from a weekly energy supply frequency of 105 hours power supply per week illustrates that post-paid low income earners have the highest energy consumption pattern while energy consumption pattern for prepaid income earners were low. Average weekly energy usage for these classes is 36.89kW/hr, 59.82kW/hr, 40.87kW/hr and 31.11kW/hr for PLIE, POLIE, POHIE and PHIE respectively as shown in Figure 2. The highest consumption average was observed with the POLIE which may be attributed to high population density and high rate of wastage due to erroneous billing system by the power supply company. This corroborates previous report that low energy prices potentially jeopardized efforts to reduce greenhouse gas (GHG) emissions [27].

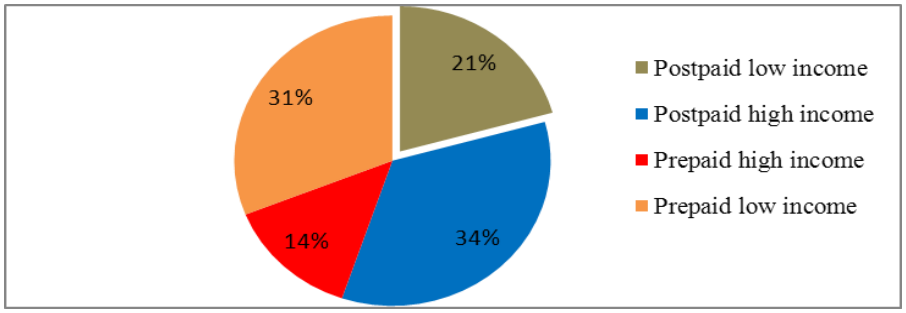

Figure 1: The category distribution in South-West zone of Nigeria

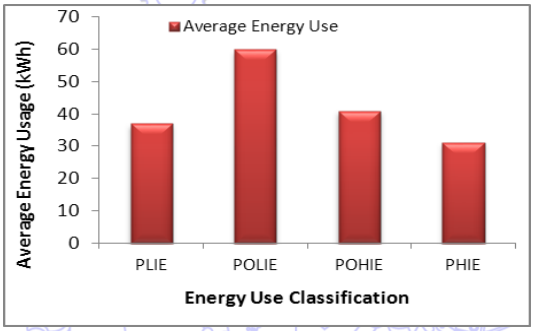

Figure 2: Average energy usage for classes of consumers

Table 4: Income-metering correlations for global warming potential

	Mean	Standard Deviation	r	r^2	Significance level (p)
POHIE	5.35	3.71	0.99	0.99	0.01
PHIE	4.45	2.54	0.99	0.99	0.01
PLIE	4.43	3.83	0.99	0.99	0.01
POLIE	8.35	3.56	0.99	0.99	0.01

Table 5: Income-metering correlations for acidification potential

	Mean	Standard Deviation	r	r^2	Significance level (p)
POHIE	0.003	0.002	0.99	0.99	0.01
PHIE	0.003	0.002	0.99	9.99	0.01
PLIE	0.003	0.002	0.91	0.83	0.01
POLIE	0.005	0.002	0.99	0.99	0.01

It was noticed that more prudence and attention were given to energy usage by prepaid meter users. The low weekly data for prepaid users show good attitudinal and behavioral change towards energy usage as opposed to the postpaid customers. Reference [11] observed similar result in a study on energy consumption. A comparison of average energy consumption shows

that both classes of consumers (low & high income earners) exhibited a significant reduction in energy wastage tendencies. However, the low income earners showed a much greater reduction in energy consumption of 38.3% when metering system was changed from post-paid to prepay. While the high income earners displayed 23.9% reduction in energy consumption due to change in metering system as shown in Figure 3. This infers that low income earners have lifestyle modification. They are more conscious of energy usage with use of prepaid metering systems. On the contrary, the high income earners seem to be less concerned about reducing the energy consumption. This can be attributed to the lifestyle which requires additional energy utilization. The category has well equipped household composition or utility gadgets such as air conditioners, freezers, washing machines, microwaves, entertainment gadgets etc. This depicts that high standard of living and material affluence significantly contributes to energy consumption. Reference [28-29] observed similar outcome in respective energy consumption studies.

Strong positive correlation exists between energy use and emission generated ($r > 0.90$; $p < 0.01$ for all classifications). The correlation was significantly strong for all the categories in terms of global warming and acidification potential except for PLIE category with less strong relationship in terms of acidification potential (Table 4 and 5). Generally, this implies that strong affinity exist between householders income and emissions generated irrespective of the metering system type. The result gives a better representation than [16] co-relationship of disposal income with energy use cum associated emissions.

Global warming causer gases emitted into the atmosphere are CO_2, CH_4 and N_2O. Reference [18] reported affluence as the primary contributor to these emissions generation rate in the society resulting in increased global warming potential. However, the categorization adopted in this study extend beyond wealth or income, it factors in metering system. The study shows that consumption from households with low income using post-paid meters (POLIE) had the highest value of 8.58 CO_2 equivalent/ functional unit. On the contrary, households with high income using prepaid meters (PHIE) recorded the lowest value of 4.46 CO_2 equivalent/ functional unit of global warming potential as shown in Figure 4. In summary, the result shows that for both classes of consumers (high and low income) post-paid consumers contribute more to global warming when compared to the prepaid users. Reference [11] led credence to this finding in a study on energy consumption and demand in tertiary institution. Prepaid users obviously have attitudinal and behavioral change as opposed to postpaid users. This further implies that prepaid metering system contributes to the enhancement of environmental integrity and economical management.

NO_x and SO_x are group of gases which increases acidification potential. Result shows that consumption from low income households using post-paid meters (POLIE) had the highest value of 3.07×10^{-3} SO_2 equivalent/functional unit. On the other hand, the high income households using prepaid meters (PHIE) recorded the lowest value of 2.59×10^{-3} SO_2 equivalent/functional unit of acidification potential as shown in Figure 5. A close observation of the pattern for acidification potential shows that the same trend was exhibited as that of global warming potential. This proves that the post-paid meter users contribute more in terms of acidification potential when compared with the prepaid consumers.

In summary, the trend of energy usage for both the prepaid and post paid consumers shows that under both income levels energy usage was minimized with the introduction of prepaid metering system. This suggests that there is direct nexus between the consumer's perception of the metering system and the energy use pattern. Most consumers exhibit high level of responsibility or lifestyle modification with energy consumption when availability is based on their economic status as opposed to the credit form of tariff system used under post-paid system of power usage. The system is a better alternative to the credit form of billing system which is fast becoming ineffective and leading to energy wastage on the part of consumers. Also, the system compensates for the seemingly unjust bills distributed at the end of each credit period. It is believed that energy supply and provision could be more effective if there is a drastic reduction in energy wastage thereby leading to a better overall efficiency of the system. Emissions from the combustion of fuel will attain an alarming level in no distant future if appropriate

measures such as reduced use of fossil fuel and environmentally friendly options of power usage are not implemented by the government.

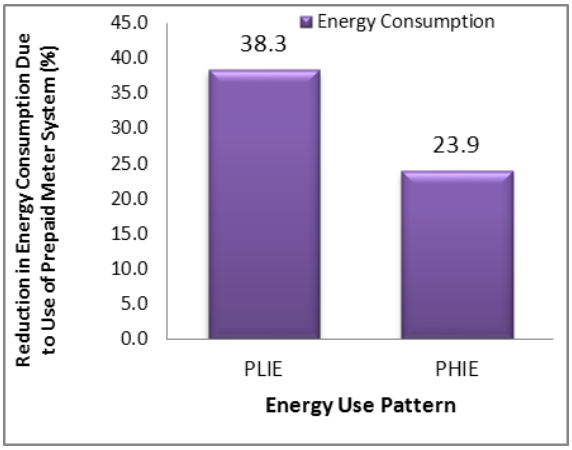

Figure 3: Energy reduction as a result of change in metering systems.

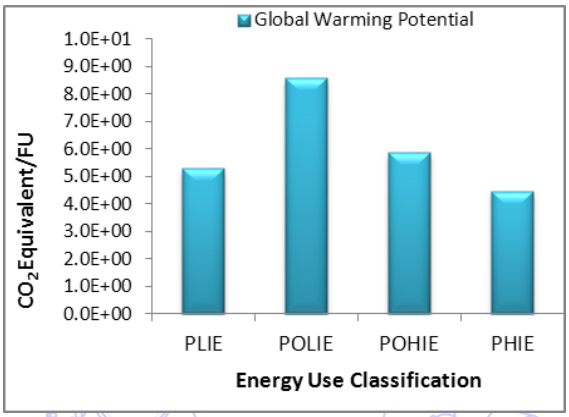

Figure 4: Global warming potential for household power consumption

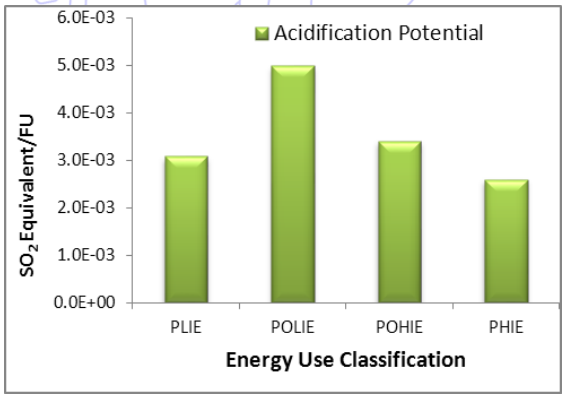

Figure 5: Acidification potential due to energy consumption pattern of different classes of consumers.

5. Conclusions

This study has been able to show that most consumers are accountable in terms of energy utilization with the introduction of prepaid metering system. It is observed that high income earners demonstrated lower propensity to reduce energy wastage

due to the high energy demand associated with their lifestyle. To this end, the current increase in electricity tariff due to privatisation of the power sector by the government in the country may be viewed as not totally having a negative effect. This is because it is most likely to aid reduction in energy consumption especially with the use of prepaid meters. The study also showed that the low income post paid energy consumers have the highest global warming and acidification potential indices while the prepaid high income consumers exhibited the lowest emission rates. However, a holistic view of the scenarios shows that the post-paid consumers (high and low income) have higher values of emission rates as compared to prepaid consumers. Therefore, to conserve the environment and resources, the full implementation of prepaid metering system as it is in consonance with global best practices should be fully embraced by all concerned stakeholders.

6. Recommendation

Government should expedite action on policy formulation and implementation in order to enforce prepaid metering system usage in Nigeria. Governmental and non-governmental bodies ought to educate and enlighten the populace on good energy consumption lifestyle to foster low emission society.

7. Recommendation for Future Research

Similar research should be carried out at other geo-political zones in Nigeria. Moreso, the scope should be extended to commercial and industrial sectors bearing in mind the intricacies associated with their classification and data collection.

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