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Energy, emissions and cost savings impact assessment of adopting energy efficient lighting in Enugu, Nigeria.

Abstract

The benefits of the use of energy efficient lighting systems are well established. However, due to lack of local data, the potential and benefits of switching to efficient lighting in Nigeria has not been studied. Based on data collected from a household survey, this paper assessed the environmental performance, economic and energy savings impacts of replacing incandescent bulbs with compact fluorescent lamps (CFL) in households in Enugu, Nigeria. The author conducted a survey of 384 households in the case study area and gathered information on key household socio-economic characteristics, equipment type and use patterns. With key parameters and features for comparison clearly stated, the paper adopts the life cycle cost method to determine electricity cost savings when an estimated number of four incandescent bulbs are replaced with a corresponding number of CFL bulbs. The result shows that the use of CFLs present good opportunities for savings in energy costs. Based on a social discount rate (SDR) of 4.25 % and an average of 5.1 hours of utilization per day, the simple payback period is 1.8 months. The result of the sensitivity analysis reveals that, both the bulb retail cost and electricity price have considerable effects on the payback period. The high retail price of CFLs in the local market (when compared to incandescent light bulbs), the proliferation of substandard CFLs and lack of end-user's awareness on their economic benefits could be seen as the major barriers hampering adoption of efficient lighting appliances. Considering the predominantly natural gas based electricity generation in Nigeria, an estimated annual emission savings of 147.3 $kgCO_2$ is possible per household per year.

Keywords: Compact Fluorescent Lamps (CFLs), Incandescent Bulbs, Households, Energy, and Emission.

1. Introduction

Providing efficient lighting solutions has become one of the priority issues to sustainable development especially in developing countries. According to data from Energy Commission of Nigeria (ECN), annual electricity consumption in the country has increased from 1,273 GWh in 1970 to 29,573 GWh in 2012 (ECN, 2013). However, this value may represent a suppressed demand considering the fact that they were derived irrespective of frequent and widespread power outages. As a result of the incessant power disruptions, there is a high ownership and use of diesel-based backup generating sets which also contributes to huge environmental pollution and emissions.

1.1 Background

Nigeria has been listed as one of the top 25 emitting nations, contributing about 0.57 % of total global emissions (Climate scorecard, 2017). The residential sector accounts for

over 50 % of the national grid electricity consumption, whereas the commercial and industrial sectors have accounted for 25 % each (ECN, 2013). Energy use in the residential sector is mainly for lighting, cooling, cooking and for other various electrical appliances such as television and radio sets. Lighting and appliances represents one of the fastest-growing electricity loads in the country and the main lighting devices used are inefficient incandescent light bulbs (ECN, 2013). The use of inefficient appliances is associated with high wastage of the electricity, a valuable key resource for the economy (ECN, 2013). It also contributes to a significant part of consumers' electricity bills and also, exacerbates emission of greenhouse gases (GHG) which has been on the increase over the past decades.[1] Compelling evidences exist in literature which show that the use of more efficient technologies could help reduce consumers' energy costs, presents a cost effective means for energy savings and emission reduction from electricity generation and distribution (Howland et al, 2009; Kushler et al, 2003). It also ensures the generation of less heat, contributing to more comfortable indoor temperature in tropical countries and thus, reducing cooling needs. However, in Nigeria, energy efficiency measures remain unpopular amongst local consumers. This is due largely, to the lack of awareness about the economic and social benefits of using energy efficient appliances (Uduma and Arciszewski, 2010) and poor regulatory and enforcement measures to mandate and support the required behavioral changes. Motivating end-users to adopt efficient lighting technologies will require creating the necessary awareness on their short- to medium-term benefits and establishing strategic policies that will enhance market diffusion.
There is little study on the potential and benefits of efficient lighting in Nigeria and the case study area due to lack of relevant household data. This empirical analysis of the specific situation in Enugu fills the data gap and through the identification of key barriers, will guide the design of effective intervention measures for the advancement of efficient lighting technologies in the country. The emission reduction assessment elucidates information on the potential contribution of the use of more efficient light bulbs in mitigating GHG emissions.

1.2 Aim of study

Specifically, the study aims to evaluate cost, energy and environmental savings that could be achieved from replacing incandescent light bulbs with CFLs of equivalent light output over a year period in a typical Nigerian household. The basis of this assessment is to establish the actual potential of the use of CFLs in terms of its possible economic benefits to end users and the environment as a whole.

2. Current status and national policy context.

2.1 The predominant use of incandescent bulbs for lighting

The ordinary name for incandescent bulb in Nigeria is "yellow bulb" because of the yellowish colour of the light rays from the bulb when it lights. Many Nigerians are not familiar with the term "incandescent". There is an estimated 500 million incandescent light bulbs in the country (Go Green Nigeria, 2013) and the metering report of the Energy Commission of Nigeria (ECN) indicates that almost 68 % of incandescent bulb wattage is 60 watts (W) (ECN, 2013). The use of incandescent light bulbs for lighting is energy intensive. Only about 5 % of total energy used by an incandescent bulb is converted to

[1] Per capita emission in Nigeria has increased from 0.1 metric tons per capita in 1960 to 0.6 metric tons per capita in 2013 (World Bank Data, 2016).

light energy; the remaining 95 % is converted to heat energy (Lebot, 2009). The energy ratings of incandescent light bulbs found in the Nigeria market are mainly 40 W, 60 W, 100 W and 200 W with price ranges from Nigerian Naira (NGN) 30 to 100 (USD 0.10 – 0.33).[2] and the power ratings of CFLs found in the local market are basically 15 W, 20 W, 26 W and 36 W with price ranges from NGN 350 to 1000 – USD 1.15 – 3.23. The relatively low prices of incandescent light bulbs when compared to CFLs largely contribute to their proliferation. This is exacerbated by the fact that majority of the population still live below the poverty threshold of USD 1.25 purchasing power parity (PPP) per day[3] (Nigeria NDC report, 2017). The low income level has also resulted to situations where households are not able to afford electricity bills and devise various illegal means to reduce energy costs. There is an insignificant manufacturing facility for energy efficient light bulbs in Nigeria and it could be interpreted that majority of light bulbs are imported. The UNDP and GEF study identified about 206 different brand names of efficient lighting products in the Nigerian market with only about 0.1 % produced locally (UNDP-GEF, 2015). The same study also estimated that 95 % of these light bulbs do not meet the required standards. It further highlights that majority of the lighting products do not have enough information to influence consumers' choice. The implication of this is that it creates a market failure that results in higher risk perception regarding investments on efficient lighting products. This results to reduced consumers' confidence and acceptance of efficient lighting technologies.

2.2 Energy efficient lighting

Energy efficiency in lighting refers to the amount of energy needed to provide suitable light output (WISIONS, 2013). The electric lamp converts electric power into light at an efficiency level determined by considering the amount of the electrical energy that can be effectively converted into light. This efficiency level is known as the "Luminous efficacy" and it depicts the level of lumens (the light output of a lamp) per watt (lm/w) of power consumed (WISIONS, 2013). The luminous efficacy is thus, an essential index for assessing the efficiency of an electric lamp. Apart from the role the electric lamp plays when considering lighting efficiency, several other factors of the lighting system such as, lighting controls, ballasts, luminaries as well as the maximum use of daylight, also contributes to its overall efficiency level.

2.3 Efficient lighting for greenhouse gas mitigation – national context

In Nigeria, the energy sector emission contribution stands at 162.73 $MtCO_2e$ (EIA, 2014; IEA, 2015) which represents about 33.12 % of total GHG emissions and electricity and heat generation accounted for about 14 % (22.76 $MtCO_2e$) of total emissions in the energy sub-sector. In reference to the SEforAll Action Agenda (SEforall-AA) 84 % of actual generation capacity in Nigeria comes from natural gas based power plants and 16 % from hydro (SEforAll-AA, 2016). There is a growing national interest in establishing policies to reduce economy-wide energy consumption and mitigate greenhouse gas (GHG) emissions (ECN, 2013). For instance, a 2 % per year increase in energy efficiency (30 % by 2030) has been detailed as part of key mitigation measures in the Nigeria's nationally determined contribution (NDC).

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[2] At Central Bank of Nigeria (CBN) exchange rate of USD 1 to NGN 305. 1 (CBN website available at: https://www.cbn.gov.ng/rates/ExchRateByCurrency.asp?CurrencyType=$USD assessed 9.6.2017)

[3] 30 % of Nigerians still leave below the poverty line of US $1.25 purchasing power parity (PPP) (Nigeria NDC report, 2017)

Nigeria is at an early stage of development and implementation of an energy efficiency plan. With support from the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF), the Nigerian government, through the Energy Commission of Nigeria (ECN) have initiated measures for the advancement of efficient lighting and appliances in the country. These includes the development of minimum energy performance standards (MEPS) for light bulbs, refrigerators and air conditioners; the acquisition of appliance testing facilities for the Standard Organisation of Nigeria (SON) and the creation of the National Centre for Energy Efficiency and Conservation (UNDP-GEF, 2015). The MEPS for lighting have been approved and MEPS for refrigerators and air conditioners have been developed but not implemented.

3. Methodology

3.1 Theoretical approach

The Nigerian lighting standard (Nigerian Industrial Standard – NIS747:2012) is used as an evaluation benchmark. Presently, the standard only considers CFLs and does not take light emitting diode (LEDs) into consideration. The savings impact of an effective implementation of this standard is assessed in this paper. The impact is based on the replacement of the existing incandescent lamps with CFLs that meets the established standards.

3.2 Selection of households and the significance of the choice of Enugu

Enugu state is located in the south-east geopolitical zone[4] of Nigeria with Enugu Urban metropolis as headquarters. Enugu urban metropolis is made up of three major local government areas: Enugu East, Enugu North and Enugu South. According to the reports of the 2006 national census exercise in Nigeria[5], there are a total of 169,422 regular households in the case study area of Enugu urban metropolis with a city population of 1,044,782 (NPC, 2006). A sample size of 384 households was calculated at 95 % confidence level and 5 % margin of error.

To ensure uniformity, 390 questionnaires were produced and randomly distributed with 130 in each of the three local government areas. The households are all connected to the national grid and were selected from those within the service area of the major electricity distribution company in Enugu, Enugu Electricity Distribution Company (EEDC).[6]

The significance of the choice of Enugu, which is the ninth largest city and one of the fastest growing economy in Nigeria based on internally generated revenue (IGR) (Enugu State Government, 2016) can be assessed from the following argument. There is a relatively high power access to power outage ratio compared to other geopolitical regions. The report of the Energy Commission of Nigeria (ECN) shows a power access to power outage ratio of 64%:36% closely only after Lagos with the maximum national power access to power outage ratio of 66%:34%. (ECN, 2013). There is a correlation

[4] There are six geopolitical zones in Nigeria: South-East, South-South, South-West, North-East, North-West, North-Central.

[5] The 2006 national population exercise is the last official census exercise in Nigeria.

[6] EEDC coordinates electricity distribution in the entire south-east geopolitical zone in Nigeria which comprises; Enugu state, Anambra state, Abia state, Imo state and Ebonyi state. The Electricity Reform Act of 2005 unbundled the then federal government owned Power Holding Company of Nigeria (PHCN) into 11distribution companies, 1 transmission company and 6 generation companies; EEDC is a product of this Reform Act (EEDC, 2016).

between average duration of power per day and annual electricity consumption (ECN, 2013). Lagos with the highest average duration of power availability per day is also characterized with the highest average annual electricity consumption of about 5000 kWh/year; Enugu has relatively high average annual electricity consumption of about 3330 kWh/year (ECN, 2013). Thus, Enugu represents a city characterized with an increasing demand for electricity and this increasing demand will be exacerbated by the current national electrification programmes and population increases. There is a need to imbibe energy efficiency measures in this region. Programmes to advance energy efficiency in this region can be applied to any region in the country or other country with growing electricity consumption.

3.3 Data source and methodological approach

Table 1 is a direct comparison of basic features of both incandescent bulb and certified CFL as published by the United States Environmental Protection Agency (US EPA).

Table 1 features of incandescent and CFL bulbs

Incandescent bulb	Compact Fluorescent Lamp (CFL)
5 % of total energy used converted to light energy and remaining 95 % converted to heat energy	Generates about 75 % less heat
Mainly 1000 hours (h) life span	Between 6000h – 10000h useful life span

Due to the skewed nature of the distribution of the power ratings of incandescent bulbs, calculation of the weighted average is necessary to determine a proxy power rating value for the incandescent lamp types which will be used to determine the baseline unit energy consumption (UEC) for lighting. Also the proxy power rating is needed in order to identify the ideal CFL replacement for the incandescent light bulbs. There are approximately, four incandescent lamps per household. The weighted average of the distribution of incandescent light bulbs in the surveyed households is 55 W[7] which is approximated to 60 W. The approximation is essential for consistency with prevalent wattage types in the region. A standard incandescent lamp efficacy is approximately 15 lm/W; and a good quality CFL bulb can achieve 60 lm/W (Letschert et al., 2013). Based on these standards, the light output or luminous flux (measured in lumens) of a 60 W incandescent light bulb will be 900 lumens. Consequently, a 15 W CFL will also produce an equivalent of 900 lumens and thus, presents an equal and adequate replacement for a 60 W incandescent light bulb. An average daily utilization of 5.1 hours was derived from the survey data. This does not deviate much from the 4.8 hours average daily duration of power access for Enugu as reported in the ECN end-use metering campaign for residential houses in Nigeria. From a 5.1 hours daily utilization, the total annual utilization time per household is approximately, 1862 hours. These parameters were used in determining the annual energy consumption in kilowatt-hour (kWh) in both the CFL and incandescent scenarios. The tariff charge in Nigerian naira (NGN) per kWh for the most dominant tariff class among the surveyed residential homes (R2S)[8] was

[7] The dominant types of incandescent light bulbs observed in the surveyed households are: 20 W, 40 W, 60 W and 100 W.

[8] The Nigerian Electricity Regulatory Commission (NERC) approved tariff charges (NGN/kWh) for 2017 for EEDC tariff classes for residential households are: R1 (4.00); R2S (30.93); R2T (34.28); R3 (48.12); R4 (46.08). The categorization of the tariff classes are based on household electricity demand level; for

adopted for the economic assessment. The United Nations Framework Convention on Climate Change (UNFCCC) Clean Development Mechanism (CDM) baseline and monitoring methodology was adapted to determine the total electricity consumption (EC) of both the incandescent and CFL light bulbs in kWh using the following equation:

$$EC = \frac{\mu h * (Pwa \times \sum n)}{1000}$$

Where:
EC = total electricity consumption
μh = mean utilization hours of lighting appliance installed in households
Pwa = weighted average of power ratings of the light bulbs used in lighting appliance
∑n = total number of incandescent light bulbs

Energy savings and correspondingly, the environmental benefits are derived through mathematical equation called the Net Energy Savings (NES)[9] derived by subtracting the total energy consumption of the CFLs (EC_{CFL}) from the energy consumption of the incandescent light bulbs($EC_{incandescent}$). This is represented as follows:

$$NES = EC_{incandescent} - EC_{CFL}$$

On a short-term basis, the high initial cost of CFL in Nigeria is seen as a major deterrent to end-users. The difference in observed retail prices with an incandescent light bulb is almost at a factor of 10. The life-cycle cost method was used to calculate savings in electricity costs from replacing incandescent bulbs with CFLs. The life-cycle cost of an appliance includes all expenditure associated with the purchase and use of the appliance. The main cost components taken into consideration are the initial retail prices for the types of light bulb and operating cost. The operating cost consists of the annual electricity cost for lighting both for the CFL and incandescent bulb types derived from the unit electricity price, and the total cost of bulbs including replacements. The life-cycle cost (LCC) is given by:

$$LCC = Pr + \sum_{n=1}^{L} \frac{OC}{(1 + DR)^n}$$

Where:
Pr = is the appliance retails price
n = is the year since purchase (the useful life period of the CFL was used as a proxy)
OC = is the operating cost
DR = is the discount rate

instance R3 demand level ranges from > 45 kVA < 500 kVA and R4 ranges from > 500 kVA < 2 MVA (EEDC, 2016).

9 The net energy savings is the difference in energy consumption between the baseline case (incandescent bulbs) and the policy case scenarios (CFLs) (McNeil et al., 2007).

The operating cost is summed up for one year. The operating cost is derived by multiplying the electricity consumption (EC) in kWh by the unit electricity price (P) in NGN per kWh as follows:

$$OC = EC \times P$$

The operating cost is divided by a discount factor $(1 + DR)^n$ to reflect the future cost in a present value basis. The simple pay-back period needed to offset the additional investments for a CFL is then derived. A sensitivity analysis was carried out to reveal the effect of electricity price and bulb retail price on the payback period.

CO_2 emissions reduction or carbon dioxide emission savings (CES) is determined by applying country data on electricity-specific emission factor (EF)[10] to the estimated NES according to the following mathematical relationship:

$$CES = NES \times EF$$

The default grid electricity-specific emission factor for Nigeria was applied to determine possible emission reduction per incandescent light bulb changed and the emission reduction ratio (ERR) was derived using the following equation:

$$ERR = \frac{E(incandescent) - E(CFL)}{E(incandescent)} \times 100\ \%$$

Where:
$E_{incandescent}$ = the resulting emission from the use of incandescent light bulbs.
E_{CFL} = the resulting emission from the use of CFL light bulbs.

One advantage of using the electricity-specific emission factor over the CO_2 emissions per kWh from electricity generation is that the former takes into consideration emissions resulting from transmission and distributional (T&D) losses, or emissions per KWh of electricity consumed (Brander et al., 2011). T&D losses accounts for about 8 – 10 % of electricity generated in Nigeria (ECN, 2013).

4. Results and discussion
4.1 Economic feasibility assessment

Efficient lighting systems such as CFL are relatively new technology in the Nigerian market and just like any other new innovation, they have higher initial investment cost, almost by a factor of ten when compared to the conventional bulbs. The economic feasibility or attractiveness of CFL will depend on if the additional investment cost can be recovered through energy cost savings within an acceptable payback period, considering end of useful life of the unit. If not, their attractiveness will be hampered. Table 2 is an economic assessment showing the advantage of investing in CFL.

Table 2 Economic analysis of usage per household

Description	Units	Incandescent bulb	CFL

[10] The CO_2 emission factor from burning natural gas reflects the full carbon content of the fuel (natural gas) under the assumption of a complete oxidation of carbon in the fuel during combustion.

Lamp type	Watt (Weighted average)	60	15
Total number of CFLs and incandescent bulbs in the surveyed households	Number	1444 (75 %)	486 (25 %)
Approx. number of incandescent bulbs per household	Number	4	
Average household size	Persons	6.2	
Initial investment	NGN per bulb	40	400
Initial investment for four bulbs	NGN for four bulbs	160	1600
Extra investment cost for CFL	NGN for four bulbs		1440
Use life	Hours	1000	8000
Daily average utilization hour	Hours	5.1 (1862 hours/year)	5.1 (1862 hours/year)
Unit electricity price (R2S Tariff charge for 2017)	NGN per KWh	30.93	30.93
Number of bulbs needed for 1862 hours	Number of lamps	8	4
Bulb purchase costs	NGN per year	320	1600
Bulb purchase costs in the LCC approach (excluding the residual use life part of the purchase costs)	NGN per year	298	372.4
Annual energy consumed	kWh	447	112
Net Energy Savings (NES)	kWh per household	335	
Annual electricity cost for lighting	NGN per year	13,822	3,456
Total LCC cost for lighting (considering the residual use life of bulbs)	NGN per year	13,842	4,045
Total cost savings (LCC approach)	NGN per year	9,798	
Simple payback period	Months	1.8	

From table 2, considering a mean utilization of 5.1 hours per day per household, replacing an average of four incandescent light bulbs of 60 W power ratings with 15 W CFL light bulbs will reduce lighting electricity consumption by 75 %, leading to 335 KWh annual energy savings per household and a total annual energy cost savings of NGN 9,798 (USD 32.11). These include benefits from extended useful life period and reduced energy consumption of CFLs. The life cycle cost was calculated using a national discount rate of 4.25 % for Nigeria adopted from the Central Intelligence Agency (CIA) World Factbook (CIA, 2017). A simple payback period of about 1.8 months is needed to recover the extra investment cost when an average number of 4 incandescent light bulbs of 60 W power ratings are replaced with corresponding number of 15 W CFLs. It could be said that efficient lighting systems promises a cost-effective way of sustainable energy consumption. It should be mentioned however, that the payback time will reduce further if a longer period of usage was considered. From the assessment, the use of CFLs in households presents potential economic benefits however they remain largely unpopular in the case study (incandescent light bulbs represents 75 % of total observed light bulbs in the surveyed households; see figure…). This could be as a result of poor awareness on their economic benefits or due to proliferation of substandard CFLs.

This study did not consider other co-benefits of using efficient lighting products in households. For instance, energy efficient light bulbs produce less heat when compared to the conventional light bulbs (EPA, 2014; Lebot, 2009) and thus, will help reduce cooling needs in households. This co-benefit aspect will also enhance economic feasibility of the use of efficient lighting in residential homes. Figure 1 is the distribution of CFLs and incandescent lamps in the surveyed households.

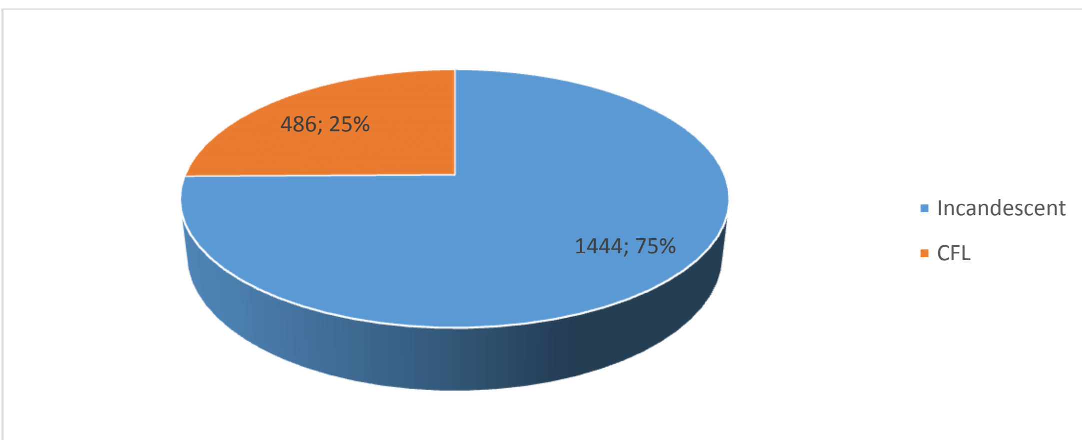

Figure 1: Distribution of CFLs and incandescent lamps in the surveyed households.

From the sensitivity analysis carried out, both the electricity tariff and the lamp's price have similar effect on the payback period. A 10 % increase in the electricity tariff rate reduced the payback period only from 1.8 months to 1.6 months. However, when electricity tariff was reduced by 10 %, the payback period increased to 2 months. On the other hand, a 10 % reduction in the price of the CFL bulb produced a payback period of 1.6 months.

4.2 Environmental assessment

CO_2 emission reduction per light bulb switched from an incandescent bulb to a CFL can be determined by multiplying the resulting electricity savings with the electricity-specific emission factor of the region in $KgCO_2$/KWh (EPA, 2014). Considering an electricity-specific emission factor of 0.43963136 $kgCO_2$/kWh for Nigeria (Brander et al., 2011), 147.3 $KgCO_2$ emissions could be reduced annually for every four 60 W incandescent light bulb replaced. Emissions from the use of the incandescent bulbs and from the use of CFLs were used to determine the emission reduction ratio (ERR). From the ERR, CO_2 emissions could be reduced by 75 % when an average of four 60 W incandescent light bulbs are replaced with a corresponding number of 15 W CFL bulbs considering an average utilization of 5.1 hours per day per household.

5. Barriers to efficient lighting

Even though the use of efficient lighting systems may offer similar or even better light output and also, are more economically viable, incandescent lamps are more prevalent in the case study area. Apart from the high initial investment costs of CFLs, several other factors have contributed to this trend. The following section discusses the major identified barriers.

Lack of awareness and appreciation of the benefits: CFL is a more cost-effective alternative to incandescent bulbs and leads to considerable savings in consumers' energy bills (see section 4.1). Inspiring end-users to adopt simple behavioural changes towards efficient technologies would involve developing strategic ways of informing and educating them on the medium- to long-term benefits of using efficient lighting technologies. Providing adequate information on the packages of light bulbs will help consumers to make appropriate purchase decisions. Such information may include lamp wattage and corresponding replacement for an incandescent bulb and also estimated period for the return on investment.

Poor electricity access: inadequate supply of electricity in the country seems to reduce the attractiveness of efficient appliances. The idea of energy savings would not make much sense to the people considering incessant power interruptions. Most of the people are of the notion that they cannot save what they do not have. Such believe, which impedes the diffusion of efficient appliances could be corrected by creating awareness programmes and educating the masses that saving energy consumption could actually improve electricity supply. Since electricity generating companies do not generate enough electricity to meet the demand of everyone at the same time, the use of efficient appliances could relieve national grid load and make electricity more available because energy saved can be made available to other regions.

Proliferation of substandard CFLs: Another major impediment to the diffusion of efficient light bulbs is the incessant proliferation of substandard products. This issue reduces consumers' confidence on the reliability of the products and discourages them from buying CFLs. This measure needs government effort and political will to enforce compliance among importers and to strengthen the responsible agency/agencies such as the Standard Organisation of Nigeria (SON) in conducting test of appliances and the confiscation of substandard products. Adequate penalties should be enforced on defaulters which will serve as deterrent to others.

Illegal connections and estimated billing systems: it was observed that some households devise various means to reduce energy costs such as bypassing electric meters to connect their loads directly to the grid thereby leading to scenarios where energy bills do not reflect actual consumption. Furthermore, the estimated billing systems is seen as a source of barrier to the advancement of the use of efficient appliances in households. It was observed that some households do not have neither of the pay-as-you-use meters nor the conventional meters. Such households get billed through an estimated billing system whereby distribution companies bill consumers based on electricity consumption in a previous month. This leads to a situation where actual monthly consumptions are not really captured.

6. Conclusion and recommendations

This paper explored the economic, environmental and energy savings potential of CFL light bulbs in comparison to the incandescent light bulbs with Enugu, Nigeria as a case study. It is expected that the findings of this work will propagate, among local consumers, the medium- to long-term benefits of choosing efficient lighting systems and thus, influence consumers' purchase decisions. The high initial costs, the proliferation of substandard products, as well as the lack of awareness on their benefits are part of the key barriers that hamper market penetration. The attractiveness of energy saving bulbs will depend on the extent the variable energy cost savings resulting from their usage would outweigh the high up-front investment cost within an acceptable payback period and also on the quality of CFLs in the local market. Based on careful assumptions guided by literatures and relevant publications, a payback period of about 1.8 months is needed to recover the extra investment costs on energy saving bulbs. Considering the durability of approximately 8000 hours of CFLs, the estimated period of return on investment signifies economic advantage in the short- to medium-term period. Government support mechanisms which focus on reducing initial costs (such as subsidies and tax exemptions) would improve attractiveness and market diffusion. Policy makers should ensure that such incentives are embedded in the country's energy efficiency policies. Furthermore, a labelling programme should be implemented; this is imperative because whereas the MEPS is necessary in phasing out inefficient appliances, comparative labelling provides appropriate information which enables consumers to compare the energy consumption of similar products. This will enhance widespread diffusion of more efficient products.

References

Brander Mathew, Sood Aman, Wylie Charlotte, Haughton Amy, and Lovell Jessica.2011. "Technical paper – Electricity specific emission factors for grid electricity." *Ecometrica.* Online at: https://ecometrica.com/assets/Electricity-specific-emission-factors-for-grid-electricity.pdf
Assessed on: 04.06.2018

Central Bank of Nigeria: "CBN exchange rates – US Dollars." 2017.
Available online at:
https://www.cbn.gov.ng/rates/ExchRateByCurrency.asp?CurrencyType=$USD
Assessed on: 09.06.2017

Central Intelligence Agency (CIA). 2017. "The World Factbook."
Available online at:
https://www.cia.gov/library/publications/the-world-factbook/rankorder/2207rank.html
Assessed on 30.05.2017

Climate Scorecard online portal
Available online at: http://climatescorecard.org/
Assessed on 01.06.2017

Energy Commission of Nigeria. 2013. "Draft National Energy Policy of Nigeria."
Available online at:
http://www.energy.gov.ng/
Assessed on: 04.04.2017

ENERGY STAR web page
Available online at:
http://www.energystar.gov/
Assessed on: 20.14.2017

Enugu Electricity Distribution Company (EEDC): Nigerian Electricity Regulatory Commission (NERC) approved tariff charges (NGN/kWh) for EEDC with effect from February 1, 2016.

Enugu State Government. 2016. "Explore Enugu State." Coffee Table Brochure Press.

Howland Jamie., Murrow Derek., Petraglia Lisa and Comings Tyler. 2009. "Energy efficiency: Engine of economic growth. A macroeconomic modeling assessment." *Environment Northeast (ENE)*, Rockpork, USA.
Available online at:
http://www.env-ne.org/public/resources/pdf/ENE_EnergyEfficiencyEngineofEconomicGrowth_FINAL.pdf
Accessed on 13.04.2017

Kushler Marty., Vine Edwards, and York Dan. 2001. "Using energy efficiency to help address electric systems reliability: an initial examination of 2001 experience." *Energy* 28 (2003): 303-317. Elsevier.
Available online at:
http://www.sciencedirect.com

Accessed on: 28.03.2017

Lebot, Benoit. 2009. “Energy efficiency and market transformation: A short overview of best practices.” A paper presented during the Inception Workshop of the UNDP-GEF project to promote energy efficiency in residential and public buildings in Nigeria. 14 July, 2009.

Leschert Virginie, Louis-Benoit Desroches, Ke Jing, McNeil Michael. 2013. “Energy efficiency – How far can we raise the bar?” Revealing the potential of best available technologies. *Energy* 59 (2013): 72-82 Elsevier. Online at:
http://dx.doi.org/10.1016/j.energy.2013.06.067
Assessed on: 19.07.2018.

National Population Commission (NPC). 2006. “National population and Housing Census of the Federal Republic of Nigeria – Population and Housing Tables: Enugu State Priority Tables.” Volume I (2006).

Nigeria Economic Report. 2014. “Improved economic outlook in 2014, and prospects for continued growth look good.” A World Bank report on the reassessment of poverty and living standards in Nigeria. Abuja, July 22, 2014.
Available online at:
https://www.worldbank.org/en/country/nigeria/publication/nigeria-economic-report-improved-economic-outlook-in-2014-and-prospects-for-continued-growth-look-good
Assessed on: 12.04.2017

Nigeria NDC Report. 2017. “UNFCCC – NDC Registry (Interim).”
Available online at: http://www4.unfccc.int/ndcregistry/Pages/All.aspx
Assessed on: 09.06.2017

Standard Organisation of Nigeria (SON). 2010. “Nigerian Industrial Standard – Self-ballasted lamps for general lighting services – Performance requirements.” *SON*, Lagos, Nigeria.

Sustainable Energy for All - Action Agenda (SEforAll-AA). 2016. “Adopted by the Inter-ministerial Committee on Renewable Energy and Energy Efficiency (ICREEE), Federal Republic of Nigeria.” Approved by National Council on Power (NACOP), July 2016.

The Go Green Nigeria Concept Note
Available online at:
http://www.gogreenng.com/about1.html
Assessed on: 30.05.2017

Uduma Kalu, and Arciszewski Tomasz. 2010. “Sustainable energy development: the key to a stable Nigeria.” *Sustainability* 2: 1558-1570.

United Nations Development Programme – Global Environment Facility (UNDP-GEF). 2015. “Nigeria Lighting Compliance Study – Quality assessment of Compact Fluorescent Lamps in the Nigerian Market.” A paper presented at the 8th International Conference on Energy Efficiency in Domestic Appliances and Lighting (EEDAL). Lucerne University of Applied Sciences and Arts, Horw, Lucerne, Switzerland. 26 – 28 August, 2015.

United Nations Framework Convention on Climate Change (UNFCCC). 2007. “Approved Clean Development Mechanism baseline and monitoring methodology AM0046 – Distribution of efficient light bulbs to households Version 2.0”
Available online at:
https://cdm.unfccc.int/methodologies/DB/5SI1IXDIZBL6OAKIB3JFUFAQ86MBEE
Assesses on: 30.04.2017

U.S Environmental Protection Agency. 2014. “Clean Energy – Calculations and References.”
Available online at:
http://www.epa.gov/cleanenergy/energy-resources/refs.html
Assessed on: 20.13.2017

WISIONS of sustainability. 2013. “LIGHTING – Energy efficient lighting for sustainability development.” Wuppertal Institute for Climate, Environment and Energy.