SHORT NOTES

Compact fluorescent lamps and electricity consumption trend in residential buildings in Ilorin, Nigeria

Bolaji F. Sule
National Centre for Hydropower Research and Development, University of Ilorin, Ilorin, Nigeria

Kajogbola R. Ajao and Habeeb A. Ajimotokan
Department of Mechanical Engineering, University of Ilorin, Ilorin, Nigeria, and

Mohammed K. Garba
National Centre for Hydropower Research and Development, University of Ilorin, Ilorin, Nigeria

Abstract

Purpose – The purpose of this study is to examine the electricity consumption trend in residential buildings using incandescent lamps and retrofitting with compact fluorescent lamps (CFLs).

Design/methodology/approach – Questionnaires were administered to capture the necessary data from three randomly selected residential estates in Ilorin, Nigeria. In total, 8,840 sampled incandescent lamps were retrofitted with CFLs. The electric energy in kilowatt hour (kWh) consumed prior to replacement for three months was compared with kWh consumption after retrofitting and analyzed employing t-tests.

Findings – The three-month average electricity consumption of ten households for the University of Ilorin GRA quarters and Lower Niger River Basin staff quarters pre- and post-installation were 20,259 and 13,010 kWh, and 46,891 and 29,588 kWh, respectively. Results show that there were significant differences between the observed and tabulated values for the pre- and post-installation of CFLs, respectively, at 5 per cent confidence level. About 40 per cent reduction in electricity consumption was achieved through deployment of CFLs in the residential households.

Originality/value – This paper demonstrates how retrofitting of incandescent lamps with CFLs can bring about possible reduction in electricity consumption in residential households in Nigeria.

Keywords Electricity, Energy consumption, Energy efficiency, Incandescent lamps, Compact fluorescent lamps, Retrofitting, Nigeria

Paper type Research paper

Materials and financial supports for this research were provided by the Energy Commission of Nigeria, Abuja and the National Centre for Hydropower Research and Development, University of Ilorin, Nigeria, and are gratefully acknowledged.
1. Introduction

An analysis of Nigeria’s electricity supply problems and prospects found that the electricity demand in Nigeria far outstrips the supply, which is epileptic in nature. The acute electricity supply hinders the country’s development (Ajao et al., 2009) and not only restricts socio-economic activities to basic human needs; it adversely affects quality of life (Ajao et al., 2009; Sambo, 2008). The objective of the electric energy system is to provide the needed energy services. Energy services are the desired and useful products, processes or indeed services that result from the use of electricity, such as for lighting, provision of air-conditioned indoor climate, refrigerated storage, appropriate temperatures for cooking, etc. (Sambo, 1997). Presently, electric energy utilization in Nigeria is far from being efficient. The potential for efficient energy utilization or conservation in residential sector is substantial as it accounts for approximately one-third of overall delivered-energy use and carbon-dioxide emissions (Business, Enterprise and Regulatory Reform, 2008; Sambo, 2005). Key factors in the growth of household electricity consumption are the number of households with access to electricity supply, penetration rates of electric appliances, the size and efficiency of appliances (Dzioubinski and Chipman, 1999) and the use of traditional incandescent lighting (Sule et al., 2010).

The use of compact fluorescent lamps (CFLs) that utilize up to 75 per cent less energy or electricity than incandescent light bulbs, can last up to ten times longer, cost little up front, and provide a quick return on investment (Energy Star, 2008; Powerline, 2005) is momentous. Thus, substantial savings can be made by simply switching from incandescent bulbs to CFLs, especially in the household sector. CFL is fluorescent lighting designed to be used in a standard (incandescent) light bulb socket. Fluorescent lighting works by passing a current through a gas-filled tube. CFLs incorporate the best features of fluorescents: high efficiency and long life and produce steady, quiet, white light (Duke Energy, 2007); which add to the aesthetics and usability of any home (Dioha et al., 2010).

This study examines how a successful replacement of incandescent lamps with CFLs could bring about possible reduction in electricity consumption in residential households.

2. Method of study

A retrofitting exercise of incandescent lamps with CFLs in organized settlements was conducted as a pilot project under the Energy Commission of Nigeria energy-efficient programme. The commission supplied to states of the federation, CFLs for the replacement of incandescent lamps. In Kwara State, three organized residential estates were selected in Ilorin, the State capital. The tool employed for the data collection was a structured questionnaire administered through house-to-house surveys of selected residential estates to capture the needed data. These surveys were drafted to obtain information on the type of lighting and their respective wattages, consumption pattern, the distribution of incandescent lamps and CFLs in these estates, average monthly
electricity consumption (kWh) and average monthly bill paid (Naira). A total of 576 questionnaires were administered at the three estates visited.

For this study, electricity bills from Lower Niger River Basin quarters and University of Ilorin GRA quarters were collected and analyzed. The electric energy in kilowatt hour (kWh) consumed prior to replacement for three months were compared with kWh consumption three months after replacement using \( t \)-test.

3. Results and discussion

In total, 73 households comprising six duplexes, seven storey buildings having six flats each and six bungalows were visited at the University of Ilorin GRA quarters. Other households surveyed include, Mandate I & II Housing Estate comprising of 347 bungalows and the Lower Niger River Basin quarters having 155 households mainly bungalows and only one duplex. These houses were retrofitted with 8,840 CFLs.

Table I depicts the distribution of building types in the sample estates and the total number of households surveyed. Tables II and III are the distribution of incandescent lamps and CFLs in the selected estates while Table IV depicts the average kWh consumed pre- and post-installation of CFLs in the University of Ilorin GRA quarters and Lower

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Name of estate</th>
<th>Duplex</th>
<th>Bungalows</th>
<th>Storey building (No. of flats)</th>
<th>BQs</th>
<th>Household total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UL-GRAQ</td>
<td>6</td>
<td>6</td>
<td>7(42)</td>
<td>19</td>
<td>73</td>
</tr>
<tr>
<td>2</td>
<td>LNRBQ</td>
<td>1</td>
<td>155</td>
<td>195</td>
<td>Nil</td>
<td>156</td>
</tr>
<tr>
<td>3</td>
<td>MT-I &amp; II</td>
<td>Nil</td>
<td>347</td>
<td>347</td>
<td>Nil</td>
<td>347</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>7</td>
<td>508</td>
<td>7(42)</td>
<td>19</td>
<td>576</td>
</tr>
</tbody>
</table>

Table I. Types of building

Notes: UL-GRAQ: University of Ilorin, GRA quarters; LNRBQ: Lower Niger River Basin quarters; MT-I & II: Mandate I & II Housing estate

<table>
<thead>
<tr>
<th>Wattage</th>
<th>No. of incandescent lamps</th>
<th>UL-GRAQ</th>
<th>LNRBQ</th>
<th>MT-I &amp; II</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td></td>
<td>10</td>
<td>30</td>
<td>250</td>
<td>280</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>127</td>
<td>76</td>
<td>1,344</td>
<td>1,547</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td>913</td>
<td>2,585</td>
<td>3,381</td>
<td>6,879</td>
</tr>
<tr>
<td>100</td>
<td></td>
<td>13</td>
<td>51</td>
<td>8</td>
<td>72</td>
</tr>
<tr>
<td>200</td>
<td></td>
<td>19</td>
<td>25</td>
<td>8</td>
<td>52</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1,082</td>
<td>2,767</td>
<td>4,991</td>
<td>8,840</td>
</tr>
</tbody>
</table>

Table II. Distribution of incandescent lamps in the selected estates

<table>
<thead>
<tr>
<th>Wattage</th>
<th>No. of CFLs</th>
<th>UL-GRAQ</th>
<th>LNRBQ</th>
<th>MT-I &amp; II</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-8</td>
<td></td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>9-12</td>
<td></td>
<td>Nil</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>13-16</td>
<td></td>
<td>33</td>
<td>5</td>
<td>Nil</td>
<td>38</td>
</tr>
<tr>
<td>17-20</td>
<td></td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>20 and above</td>
<td></td>
<td>Nil</td>
<td>26</td>
<td>8</td>
<td>34</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>36</td>
<td>34</td>
<td>13</td>
<td>80</td>
</tr>
</tbody>
</table>

Table III. Distribution of CFLs in the selected estates before retrofitting
Niger River Basin quarters, respectively. Figures 1 and 2 show the variation of incandescent lamps and CFLs in the selected estates while Figure 3 shows the average monthly electricity consumption in these quarters during the study period.

The objective is to determine whether the energy consumption of the sampled households differ before and after the installation of CFLs.

3.1 Hypothesis

\( H_0 \). The energy consumption before the installation of CFLs is not significantly different from energy consumption after the installation of CFLs.

\( H_1 \). The energy consumption before the installation of CFLs is significantly different from energy consumption after the installation of CFLs.

That is, \( H_0: \mu_1 - \mu_2 = 0 \) vs \( H_1: \mu_1 - \mu_2 \neq 0 \).

3.2 t-Tests analysis (Keller, 2009)

\[
t = \frac{\bar{X}_1 - \bar{X}_2 - (\mu_1 - \mu_2)}{\sqrt{s_p^2(n_1 + n_2)/n_1n_2}} - t_{(\alpha/2),n_1+n_2-2}
\]  

\( t \) is

<table>
<thead>
<tr>
<th>Estate</th>
<th>December 2009</th>
<th>Pre-installation</th>
<th>Post-installation</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>UL-GRAQ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumption</td>
<td>17,398</td>
<td>23,652</td>
<td>19,728</td>
<td>7,249</td>
</tr>
<tr>
<td>(kWh)</td>
<td>15,525</td>
<td>13,359</td>
<td>13,010</td>
<td>36</td>
</tr>
<tr>
<td>LNRBQ</td>
<td>36,972</td>
<td>56,784</td>
<td>46,917</td>
<td>17,303</td>
</tr>
<tr>
<td>Consumption</td>
<td>34,216</td>
<td>28,184</td>
<td>26,364</td>
<td>37</td>
</tr>
<tr>
<td>(kWh)</td>
<td>29,588</td>
<td>26,364</td>
<td>29,588</td>
<td></td>
</tr>
</tbody>
</table>

Table IV. Average monthly kWh of electricity consumed in University of Ilorin GRA quarters and Lower Niger River Basin quarters

Figure 1. Graph of distribution of incandescent lamps in selected estates
Where:

\[ s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \]

3.2.1 For University of Ilorin GRA quarters.

\[ \bar{X}_1 = 525.92, \bar{X}_2 = 328.81, s_1^2 = 5,806.04, s_2^2 = 5,339.84, n_1 = n_2 = 73. \]

Therefore:

\[ s_p^2 = \frac{(72 \times 5,806.04) + (72 \times 5,339.84)}{73 + 73 - 2} = 5,572.94 \]
and thus:

\[
t = \frac{(525.92 - 328.81) - 0}{\sqrt{5,572.94((73 + 73)/(73 \times 73))}} = 15.9519
\]

The tabulated \( t \)-value at 5 per cent significance level:

\[
t_{(\alpha/2), n_1+n_2-2} \Rightarrow t_{(0.05/2),310} = 1.960
\]

3.2.2 For Lower Niger River Basin quarters.

\[
\bar{X}_1 = 474.95, \bar{X}_2 = 317.08, s^2_1 = 7,988.69, s^2_2 = 5,205.36, n_1 = n_2 = 156.
\]

Therefore:

\[
s^2_p = \frac{(155 \times 7,988.69) + (155 \times 5,205.36)}{156 + 156 - 2} = 6,597.025
\]

and thus:

\[
t = \frac{(474.95 - 317.08) - 0}{\sqrt{6,597.025((156 + 156)/(156 \times 156))}} = 17.1661
\]

The tabulated \( t \)-value at 5 per cent significance level:

\[
t_{(\alpha/2), n_1+n_2-2} \Rightarrow t_{(0.05/2),310} = 1.960
\]

Since the calculated values (15.9519 and 17.1661) are greater than the tabulated respective values (1.977 and 1.960), the null hypothesis is rejected. Consequently, there exists a significant difference in the energy consumption after retrofitting with CFLs in the sampled households.

4. Conclusion

In total, 8,840 sampled incandescent lamps were retrofitted with CFLs in three randomly selected residential estates in Ilorin, Nigeria. The electric energy in kWh consumed prior to retrofitting for three months were compared with kWh consumption after retrofitting for three months. About 40 per cent reduction in electricity consumption was achieved after the deployment of CFLs which depicts that efficient house lighting with CFLs will conserves significant electric energy for other purposes. The employment of CFLs in place of incandescent bulbs will not only reduce the quantity of electricity consumed but also a measure for mitigation of climate change by reducing the amount of carbon dioxide emissions.

References


Further reading


About the authors

Bolaji F. Sule is currently the Director, National Centre for Hydropower Research and Development, University of Ilorin, Nigeria. He received his BEng from the University of Benin, Nigeria and his MSc and PhD from Cornell University, USA. He is a distinguished Professor with many awards.

Kajogbola R. Ajao (PhD) is a Lecturer in the Department of Mechanical Engineering, University of Ilorin, Nigeria. His research area is in renewable energy systems (RES) and he specializes in wind energy.

Habeeb A. Ajimotokan is an Assistant Lecturer and a PhD student in the Department of Mechanical Engineering, University of Ilorin, Nigeria. His areas of research focus on RES, energy management, engineering education and sustainable manufacturing. Habeeb A. Ajimotokan is the corresponding author and can be contacted at: hajims@unilorin.edu.ng

Mohammed K. Garba is an Assistant Research Fellow at the National Centre for Hydropower Research and Development, University of Ilorin, Nigeria and also a PhD student in the University of Ilorin, Nigeria.

To purchase reprints of this article please e-mail: reprints@emeraldinsight.com

Or visit our web site for further details: www.emeraldinsight.com/reprints