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A collective approach to reducing carbon dioxide emission: A case study of four University of Lagos Halls of residence

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ABSTRACT

A major focus of existing literature on energy conservation is the modelling and quantification of energy savings and the corresponding carbon dioxide emissions from lightings. While many studies have established theoretical frameworks concerning these issues, very little documentation exists relating to energy savings and emission levels in students' hostels. This paper considers the lighting efficiency improvement of four University of Lagos halls of residence for the purpose of quantifying energy saving and the minimization of carbon dioxide that can be made. Compact fluorescent lamps are considered alternatives to the current primary usage of conventional fluorescent and incandescent bulbs. The existing electricity consumption data obtained from energy audit are used in combination with conversion factors to estimate the annual CO_2 contributed to the atmosphere by lighting in each of the buildings. The result of the study shows that over 45% reduction in carbon dioxide emission can be achieved. There is a lot individuals can do to reduce the emissions, for example, using energy saving appliances, turning off appliances when not in use, less use of fossil fuels, are simple measures that can be adopted to reduce annual carbon footprint, improve economic growth, enhance environment, health and save the planet.

1. Introduction

The need to reduce carbon dioxide emission has now become everybody's concern. This is because its adverse effects are being experienced worldwide [1]. One very obvious way to contribute to the fight against green house gas emission is to employ energy efficiency and conservation practices.

Energy efficiency is the use of technology that requires less energy to perform the same function. Energy efficiency involves using technology to reduce the amount of energy used [2]. Examples include using more efficient lighting, better building management, more energy conserving windows, or more fuel efficient automobiles. A compact fluorescent light bulb that uses less energy to produce the same amount of light as an incandescent light bulb is an example of energy efficiency. Energy conservation is any behaviour that results in the use of less energy. Energy conservation involves behavioural changes, such as switching off lights, utilizing daylight to reduce the need for artificial lighting, turning down thermostats or switching off computers when not in use, to reduce energy consumption. The decision to replace an incandescent light bulb and normal fluorescent tube with a compact fluorescent lamp is an example of both energy efficiency and conservation (technology may provide an option but it is up to society or individual to adopt it). The combination of energy efficiency and energy conservation offers the greatest energy saving, cost savings and CO_2 reduction in related energy consumption emission [3–11].

Efficiency and conservation are key components of energy sustainability [12]. Sustainability as a concept encourages every generation to meet its energy needs without compromising the energy needs of the future generations. It focuses on long term energy strategies and policies that ensure adequate energy to meet today's needs, as well as tomorrow's.

Some of the benefits attributed to energy efficiency and conservation include reduction in energy consumption, operating cost, duration of lighting fixture replacement, the heat generated by the incandescent lamps and improvement in energy performance of buildings [13–15]. Others include participation in the global energy sustainability and contribution to the fight against greenhouse gases [16].

Human activities like rise in the use of fossil fuels for electricity consumption, transportation, deforestation, industrialization, landfills, interference with the natural water or carbon cycles, have increased the amount of green house gases and thus the carbon foot print of individuals and organizations. Therefore every individual is contributing to the phenomenon of global warming caused by the

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Nomenclature

CO_2	carbon dioxide
TPD	total power demand (W)
SW	system wattage (W)
kWh	energy consumption
CFL	compact fluorescent lamps
DLI	distance learning institute
n	number of lamps
F_d	demand factor
TOE	tonnes of oil equivalent
Subscript	
d	demand

green house effect. The effect is already being felt in many parts of the world [17,18].

A total carbon footprint/emission quantification would include energy related emissions from human activities – that is, from heat, light, power and refrigeration and all transport related emissions from cars, freight and distribution. By measuring the carbon footprint, the energy consumer gets a better sense of what impact and the lifestyle that deserve the greatest attention [19].

More than 40% of final energy consumption in developing countries is due to the residential and tertiary sector, the major part of which is buildings [20]. Worldwide, buildings account for almost a third of final energy consumption and are an equally important source of CO_2 emissions [21]. Inappropriate energy use and increasing concern for climate change calls for new and improved methods for the prediction of building energy consumption. This is especially important in design of new-built and refurbishment of low energy and net-zero energy buildings where there are high uncertainties in the estimation of collected energy and used energy [22].

Building energy performance assessment is crucial to ascertain the efficiency of energy use in buildings and is the basis to make any decision for enhancing energy efficiency. In order to assess the energy performance of existing buildings quantitatively, the energy use of the assessed buildings should be quantified first. The quantified energy use will be then used to compare with the assessment criteria to determine the energy performance quantitatively [23].

The Kyoto protocol (an international agreement adopted in 1997 in Kyoto, Japan) of United Nations Framework Convention on Climate Change aims at globally and collectively reduce greenhouse gas emissions by 63.9% of the 1990 levels by 2012. Nigeria emitted a total of 77.75 million tonnes of carbon dioxide in 2009 compared with the 100.16 million tonnes emitted in 2008, thus ranks the 46th in world carbon dioxide emission list. Energy efficiency is essential in addressing the future management of climate change adaptation strategies [10,24].

University of Lagos electrical services are supplied by Power Holding Company of Nigeria (PHCN) with a peak power demand of some 6 MW and average daily energy consumption of 74,726.63 kWh from incoming feeders. Two sets of 1 MW diesel generating sets consuming 140 l/h generate standby power when the PHCN supply fails. The consumption on PHCN and each of generating sets supply contribute 93.41 tonnes of CO_2 daily and 0.3752 tonnes of CO_2 per hour respectively.

The University community is flooded with conventional light bulbs (incandescent and fluorescent) installed to provide illumination. There is therefore, a need to gradually move away from the present inefficient practices towards achieving green society – environmental friendly and less harmful in its energy production and usage. Unconsciously to the users, many of these light bulbs are left on in class rooms, outdoor lighting, and apartment building hallways. In Nigeria, the majority of these light bulbs are powered by burning fossil fuels in electric generators.

According to University of Lagos Students Information Handbook 2009–2011 [25], 9031 students are currently accommodated in the University's 15 halls of residence. The capacities in the Halls under study are Erastus Akingbola 108, Mariere 450, King Jaja 630 and Moremi 885. The halls are also of different ages; the latest Erastus Akingbola was built in 2006, King Jaja 1974, while Mariere and Moremi were built in the early/late 60s. Energy efficiency and Sustainability were not critical issues at the time these buildings were constructed for use. It is therefore necessary to consider how they can be retrofitted to be in line with present ideas of energy conservation [26].

The occupants of these buildings have a high degree of control over electricity use with the choice of switching off appliances when not in use, even though they do not have an immediate economic incentive for conservation, they do not pay for electricity. However, with sufficient level of awareness on this subject through jingles, research publications, hand bills, wall bills on energy saving tips, regular monitoring and display of energy consumption data and charts on bill boards, they are likely to make decisions that are beneficial to the environment, by letting them know their current resource use and the associated problems, thus motivating and empowering them morally or ethically to conserve these resources [27,28].

The paper focuses on reducing the carbon dioxide emission in the atmosphere and uses a survey of four buildings within University of Lagos, Nigeria as a test case. It compares the present electricity consumption of four halls of residence within University of Lagos with proposed efficient measures and illustrates how consumers can estimate the carbon footprint in tonnes of oil equivalent on the kilowatts of energy consumed. Light bulb/lamp is the only energy consuming device considered. This work compares the present carbon dioxide contribution of the inefficient status of these buildings and proposes carbon emission saving strategies the University could adopt to minimize greenhouse gases. This study will help students and other members of the University community to understand how small, daily activities have a big impact on the environment.

Lighting is a large and rapidly growing source of energy demand and greenhouse gas emissions. In 2005 grid-based electricity consumption for lighting was 2650 TWh worldwide, which was about 19% of the total global electricity consumption [13]. Global electricity consumption for lighting is distributed approximately 28% to the residential sector, 48% to the service sector, 16% to the industrial sector, and 8% to street and other lighting. In the industrialized countries, national electricity consumption for lighting ranges from 5% to 15%, on the other hand, in developing countries the value can be as high as 86% of the total electricity use [29].

Switching from traditional light bulbs (called incandescent) to CFLs is an effective, simple change that everyone can make right now. Efficient lighting has been found in several studies to be a cost effective way to reduce CO_2 emissions [30,31]. Making this change will help in using less electricity at home and prevent greenhouse gas emissions that lead to global climate change. A companion paper titled Energy (Lighting) Audit of four University of Lagos Halls of Residence [32] has discussed the cost implication of this retrofitting.

2. Methodology

Data for the study was collected through library research including surfing Internet, the use of questionnaires and personal interviews on students (occupants), management of the halls' facilities, shop owners and daily energy consumption data from the

University's service area. The occupants of each room represent a respondent in this study. In Erastus Akingbola Postgraduate Hall, Jaja Hall, Mariere Hall and Moremi Hall, a total number of 67, 188, 143 and 189 questionnaires were administered.

The existing electricity consumption data obtained from retrieved questionnaires are used in combination with conversion factors to estimate the annual CO_2 contributed to the atmosphere by lighting in each of the buildings.

The following assumptions are made

1. The halls of residence are occupied for an average of 300days in a year (both Full-time and DLI).
2. The average duration of energy use in halls of residence is 15 h/day, while the average duration of energy used in the analysis of the 3rd floor System Engineering building is 8 h.
3. Compact Fluorescent Lamps (CFL) of 18 W is to replace both the normal fluorescent tubes and incandescent bulbs currently installed.
4. The demand factor of 100% is used because the University provided one power switch for each of the rooms.
5. The occupants (at least four persons per room) of these rooms do not leave at the same time, as they are from different departments and faculties.

The existing lighting fittings are basically the 2 ft and 4 ft fluorescent tubes, with few incandescent types. These existing fixtures which are much larger with poor reliability require more maintenance, proper alignment and takes time to install. The proposed high quality CFLs on the other hand are electronics, require less maintenance, less installation cost, and require little or no technical replacement skills. In addition, they are brighter to enhance visibility and readability, have longer life-span of up to 10,000 h (5years) (based on 5 h daily use) and help take step towards easing the threat of global climate change [28]. Based on the above advantages, the 18 W CFL as shown in Fig. 1 is used for all analysis in this study.

2.1. Theory

2.1.1. Energy consumption from lighting

The system wattage (SW) of each room computed depends on the type of lighting fitting as provided by the manufacturer and the number of lighting points. The total power demand (TPD) in kW for each building was estimated. TPD is the amount of electricity being pulled out of the power grid at any given moment. TPD is calculated as follows,

Fig. 1. 18 W compact fluorescent lamp.

$$\mathrm{TPD} = \frac{\mathrm{SW}}{1000} \times n \times F_d \quad (\text{in KW}) \tag{1}$$

where n is the number of lamps used in any particular room and F_d is the demand factor. F_d is the assumed average percentage of available lighting used at a building's peak time. For a building of the type under consideration, the demand factor is taken as 100% i.e. all the lights are always switched on.

The conversion factors in [33] and the BP Statistical Review of world Energy 2010 [34] (Appendix A) are used to obtain the tonnes of oil equivalent of the total wattage as:

$$\mathrm{TOE} = \frac{\text{Total Watts} \times 1\,\text{kW} \times 1\,\text{ton of oil equivalent} \times \text{light duration} \times \text{days in the year} \times 1\ \text{year}}{1000\,\text{Watts} \times 12000\,\text{kWh} \times 1\,\text{day} \times 1\,\text{year}} \tag{2}$$

The annual CO_2 emitted by the energy consumed on lighting to the atmosphere is obtained as in [35].

$$\text{Annual tonnes of } CO_2 \text{ emitted by lighting} = \frac{\text{Total Watts} \times 1\,\text{kW} \times 1.25 \times 10^{-3}\ \text{ton of } CO_2\ \text{light duration} \times \text{days in a year} \times 1\,\text{year}}{1000\,\text{Watts} \times 1\ \text{kWh} \times 1\,\text{day} \times 1\,\text{year}} \tag{3}$$

All these calculations are performed for each of the four buildings. The energy consumption is given in Eqs. (2) and (3).

2.2. Results

The summary of the results of the carbon dioxide emitted by energy consumption in lighting use is presented in Table 1. It shows existing and proposed total power demand, annual oil equivalent of the energy consumption carbon dioxide emission and savings due to inefficiency and efficiency respectively.

With the total power demand and average of 15 h of lighting use in these halls of residence per day, Jaja releases the highest of carbon dioxide into the atmosphere; possibly because it has the

Table 1
Summary of the carbon footprint of the current and proposed luminaire.

Serial no.	Variables		Erastus Akingbola Postgraduate Hall	Jaja Hall	Mariere Hall	Moremi Hall
1	Total power demand (W)	Existing	6270	12,882	11,442	11,364
		Proposed	3384	6624	3762	5760
2	Annual oil equivalent of the energy consumption (tonnes of oil equivalent)	Existing	2.35	4.83	4.07	4.26
		Proposed	1.27	2.48	1.41	2.16
3	Annual carbon dioxide emission to the atmosphere (tonnes of CO_2/year)	Existing	35.27	72.26	60.99	63.92
		Proposed	19.04	37.26	21.16	32.4
4	Savings in CO_2 emission	%	46.0	48.4	65.3	49.3

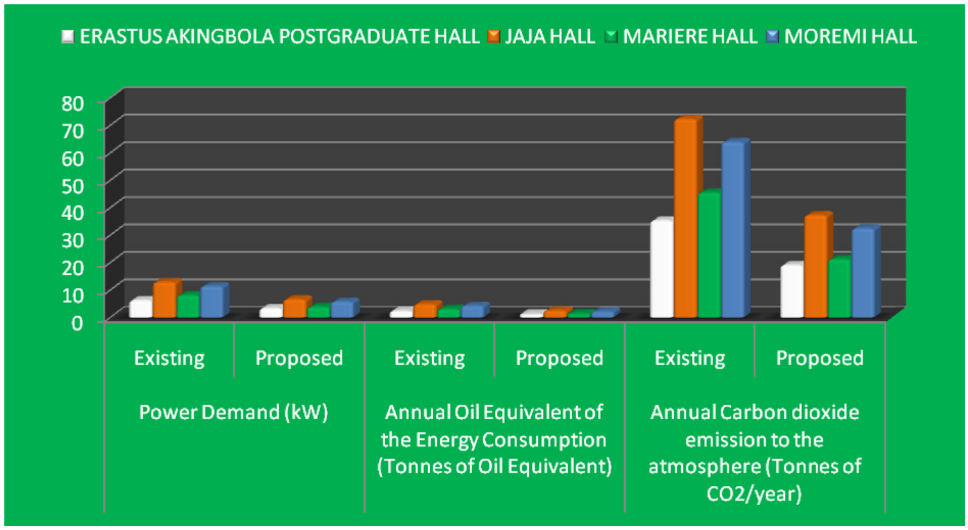

Fig. 2. The results of the annual energy consumption and carbon dioxide emissions due to lighting use in the buildings.

Table 2
Summary of estimated savings in wattage, energy consumption and carbon dioxide emission with the implemented energy efficiency measure.

Fluorescent tubes Estimation of energy consumption			Compact fluorescent lamps (CFLs) Estimation of energy consumption		
Items	Quantity	Units	Items	Quantity	Units
Total wattage	1.152	kW	Total wattage	0.772	kW
Overall daily hour of use	8	h	Overall daily hour of use	8	h
No of working days in a year	250	Days	No of working days in a year	250	days
Oil equivalent of the energy consumption	0.192	Tonnes of oil equivalent	Oil equivalent of the energy consumption	0.129	Tonnes of oil equivalent
CO_2 emitted to the atmosphere	2.88	Tonnes of CO_2	CO_2 emitted to the atmosphere	1.93	Tonnes of CO_2
Savings in CO_2 emission			33%		

By the measure taken in this floor alone, CO_2emission has been reduced by almost 33%.

widest structure and highest number of corridors that necessitated the present power demand. This is followed by Moremi, Mariere and Erastus Akingbola hall in that order. The percentages of CO_2 saved respectively are 48.4, 49.3, 65.3 and 46.0.

Opportunity for lowering the carbon dioxide level is highest in Mariere hall possibly because it is the oldest of all the halls and it is compact physically.

Fig. 2 presents the pictorial differences in total power demand, annual oil equivalent of the energy consumption, carbon dioxide emission and savings.

An actual implementation of the exercise carried out for the Halls of residence is discussed using the 3rd floor of the System Engineering building, Faculty of Engineering University of Lagos as an example. The building is presently occupied by the National Centre for Energy efficiency and Conservation (NCEEC), which had initially been equipped with conventional fluorescent tube lighting. Table 2 summarizes the estimated savings in total wattage, energy consumption (for 8 h per day) and carbon dioxide emission with the implemented energy efficiency measure.

3. Conclusion

The only measure considered in this study in reducing the carbon dioxide emission in the four halls of residence within University of Lagos is through energy efficiency and conservation in light retrofitting, that is, replacement of in-efficient light bulbs with high quality energy saving lamps (CFLs) resulting on the average of over 45% in the buildings.

There is a lot these and other energy consumers can do to reduce the emissions, for example, using energy saving appliances at home, less use of vehicles that utilize fossil fuels, using less electricity or using CFLs, lighting control and daylight are some of the simple things that can be practiced to reduce annual carbon footprint. Every enlightened individual can thus help in economic growth, save environment, health and the planet by reducing carbon footprints.

The result can be replicated in all our Universities especially the first and second generation. One can easily imagine the huge savings in energy that will accrue on the campuses.

The results of this study have provided driving forces towards conducting this same survey on all buildings within and outside the University. This will make useful data available for further research in this and allied studies.

Appendix A.

Conversion factors (taken from [33,34])
1 kW = 1000 W
12,000 kWh = 1 tonne of oil equivalent
1 l = 2.68×10^{-3} tonnes of CO_2
1 kWh = 1.25×10^{-3} tonnes of CO_2

References

[1] EIA (Energy Information Administration), International Energy Annual 2006, Available from http://www.eia.doe.gov, 2006.
[2] I.H. Ibrik, M.M. Mahmoud, Energy efficiency improvement by raising of power factor at industrial sector in palestine, Journal of Applied Polymer Science 2 (2002) 907–911.
[3] E.D. Guy, N.S. Levine, GIS modelling and analysis of Ohio's CO_2 budget: mitigating CO_2 reforestation, The Ohio Journal of Science 101 (2001) 34–41.

[4] B. Joseph, D. Jini, S.U. Ajisha, Fight global warming with genetically altered trees, Asian Journal of Biotechnology 3 (2011) 337–344.
[5] G. Branco, B. Lachal, P. Gallinelli, W. Weber, Predicted versus observed heat consumption of a low energy multifamily complex in Switzerland based on long-term experimental data, Energy and Building 36 (2004) 543–555.
[6] R. Haas, H. Auer, P. Biermayr, The impact of consumer behavior on residential energy demand for space heating, Energy and Buildings 27 (1998) 195–205.
[7] S. Cohen, C. Goldman, J. Harris, Energy savings and economics of retrofitting single family buildings, Energy and Buildings 17 (1991) 297–311.
[8] G.O. Santin, I. Laure, H. Visscher, The effect of occupancy and building characteristics on energy use for space and water heating in Dutch residential stock, Energy and Buildings 41 (2009) 1223–1232.
[9] O.T. Masosoand, L.J. Grobler, The dark side of occupants' behaviour on building energy use, Energy and Buildings 42 (2) (2010) 173–177.
[10] C.D. Beal, E. Bertone, R.A. Stewart, Evaluating the energy and carbon reductions resulting from resource-efficient household stock, Energy and Buildings 55 (2012) 422–432.
[11] J. Widén, M. Lundh, I. Vassileva, E. Dahlquist, K. Ellegård, E. Wäckelgård, Constructing load profiles for household electricity and hot water from time-use data–modelling approach and validation, Energy and Buildings 41 (7) (2009) 753–768.
[12] The Need Project, Energy Efficiency, Intermediate Energy Infobook, Manassas, VA, 2008, p. 49.
[13] L. Halonen, E. Tetri, P. Bhusal, Guidebook on energy efficient electric lighting for building, Annex 45 (2010) 1–376, http://lightinglab.fi/IEAAnnex45, ISBN 978-952-60-3229-0 (pdf), ISSN 1455-7541.
[14] F. Flourentzou, C.A. Roulet, Elaboration of retrofit scenarios, Energy and Buildings 34 (2002) 185–192.
[15] S.E. Chidiac, E.J.C. Catania, E. Morofsky, S. Foo, A screening methodology for implementing cost effective energy retrofit measures in Canadian office buildings, Energy and Buildings 43 (2011) 614–620.
[16] K. Makinen, L. Neij, Good practices in the public sector: WEC-ADEME Case Study, http://www.worldenergy.org/documents/ee_case_study_good_practices_public_sector.pdf, 2010, pp. 1–33 (accessed 06.08.2012).
[17] O.C. Eneh, Managing Nigeria's environment: the unresolved issues, Journal of Environmental Science and Technology 4 (2011) 250–263.
[18] O. Anomohanran, Estimating the greenhouse gas emission from petroleum product combustion in Nigeria, Journal of Applied Polymer Science 11 (2011) 3209–3214.
[19] M. Ghorbani, A.R. Koocheki, M. Motallebi, Estimating the greenhouse gases emission and the most important factors in dairy farms (Case study Iran), Journal of Applied Sciences 8 (2008) 4468–4471.
[20] L. Pérez-Lombard, J. Ortiz, C. Pout, A review on buildings energy consumption information, Energy and Buildings 40 (2008) 394–398.
[21] I. Farrou, M. Kolokotroni, M. Santamouris, A method for energy classification of hotels: a case-study of Greece, Energy and Buildings 55 (2012) 553–562.
[22] H. Brohus, C. Frier, P. Heiselberg, F. Haghighat, Quantification of uncertainty in predicting building energy consumption: a stochastic approach, Energy and Buildings 55 (2012) 127–140.
[23] S. Wang, C. Yan, F. Xiao, Quantitative energy performance assessment methods for existing buildings, Energy and Buildings 55 (2012) 873–888.
[24] R. Okere, Nigeria ranks 46th in world carbon dioxide emission list, energy, The Guardian Newspaper 28 (11725) (2011) 43.
[25] University of Lagos, Student Information Handbook (2009-2011), Student Affairs Division, Office of the Vice Chancellor, Lagos, Nigeria, 2009, pp. 70, 94–95.
[26] J. Kariyeva, Lighting Efficiency Feasibility Study of Three Ohio University Buildings, in: A Thesis Presented to the Faculty of the College of Arts and Sciences of Ohio University, June 2006, 2006, pp. 1–72.
[27] M. Murray, J.E. Petersen, Payback in currencies of energy, carbon dioxide and money for a 60 KW Photovoltaic array, in: Proceedings of the American Solar Energy Society, Portland OR, 2004, pp. 431–437.
[28] E.J. Petersen, V. Shunturov, K. Janda, G. Platt, K. Weingerger, Dormitory residents reduce electricity consumption when exposed to real-time visual feedback and incentives, International Journal of Sustainability in Higher Education 8 (1) (2007) 16–33.
[29] Mills E., 2002. Why we're here: the $320-billion global lighting energy bill. Right Light 5, Nice, France, pp. 369–385.
[30] D. Ürge-Vorsatz, A. Novikova, L. Paizs, Non-residential buildings for mitigating climate change: summary of the findings of the intergovernmental panel on climate change. Improving Energy Efficiency in Commercial Buildings Conference. Frankfurt, http://www.lightinglab.fi/IEAAnnex45/guidebook/1_introduction.pdf, 2008 (accessed 06.08.2012).
[31] McKinsey Global Institute, The carbon productivity challenge: Curbing climate change and sustaining economic growth. http://www.mckinsey.com/mgi/publications/Carbon_Productivity/index.asp, 2008 (accessed 04.07.2008).
[32] S.M. Abolarin, A.O. Gbadegesin, B.M. Shitta, O. Adegbenro, Energy (Lighting) audit of four University of Lagos Halls of residence, Journal of Engineering Research 16 (2 (June)) (2011) 1–10.
[33] D. Kusic, Carbon footprint of light bulbs, in: Drexel University GK12 Program, National Science Foundation, School of District, Philadelphia, Drexel University, 2007, pp. 1–6.
[34] BP Statistical Review of world Energy, 1 St James's Square London SW1Y 4PD, UK, 2010, pp. 44.
[35] Kusic, D., Carbon footprint of light bulbs, Drexel University GK12 Program, National Science Foundation, School of District, Philadelphia, Drexel University, http://gk12.coe.drexel.edu/modules/doc/Dara_Kusic/Environments_05_carbon_footprint_activity.pdf, 2007, pp 1–6.