ACHIEVING ZERO ELECTRIC LIGHTING DURING THE DAY IN BUILDINGS IN NIGERIA

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ABSTRACT

In Nigeria, like in many parts of Africa, the electric power sector has been bedeviled with many stubborn problems that have seemingly refused to be solved resulting in power outages thereby plunging building occupants into darkness and robbing them of the opportunity to carry out legitimate and profitable power related activities. The problems in the power sector are obvious yet some designers and developers have continued to design and produce building outcomes that rely heavily on electric power to light building interiors despite the abundant sunlight that nature has blessed the country with. It is disturbing to note that in a bright sun-bashing afternoon some activities in buildings such as reading, writing, cooking, washing etc. could not take place effectively without turning on the electric lights. This paper seeks to create awareness and alert designers, developers and building owners that interior space could be lit naturally which offers, on a platter of gold, zero running cost. To do this, the phenomenological approach for evaluating problem based learning using case study and observation tools were used. Three buildings A, B and C (one-bedroom and two three-bedroom bungalows respectively) were selected. The selection was based on the fact that they are among the commonly found residential buildings in our ever growing towns and cities across Nigeria. The day lighting conditions in all the interior spaces were observed, floor areas were measured and the occupants were asked if each space was bright enough for human activities intended in such spaces. Data were collected and presented. After simple mathematical computations, the results show that in Buildings A and C the percentages of floor areas with good day lighting were 49.72 and 65.36 respectively. While in Building B, all interior spaces were adjudged to be adequately lit naturally.

Keywords: *Building interior, Building occupant, Daylighting, Light pipe, Roof light, Side light*

INTRODUCTION

Just few decades ago, natural lighting was the main source of light in buildings; artificial lights supplemented the natural light.

It is glaringly clear from researches carried out that human beings have high preference for natural light in the built environment because of it positive effects on occupants health and satisfaction as stressed by Farley and Veitch, 2001; Boyce, 2003; Chang and Chen, 2005; Galasiu and Veitch, 2006.

Utility costs for a building can be decreased when daylighting is properly designed to replace electrical lighting (Edwards and Torcellini, 2002).

The energy consumption of commercial buildings in the United State demonstrates the importance of saving energy. The Department of Energy's office of Building Technology, State and Community programs (BTS) 2000 Data book Stated that commercial buildings consumed 32% of United State electricity in 1998 of which 33% went to lighting.

Electric lighting not only produce significant electric load on a building but also adds excessive cooling load. This is outside the negative impact on the environment where carbon monoxide is released when fossil fuel is burned to produce electricity. This process causes global warming.

On the other hand, daylighting has been associated with higher productivity, positive attitudes, reduced fatigue and reduced eye strain (Edwards and Torcellini, 2002).

Nigeria is blessed with good quality of sunlight across the country. This is a great and readily available resource which can be used to illuminate building interiors satisfactorily.

Given the advantages stated above and the epileptic power supply in the country, Nigeria should have taken a forefront position in daylighting utilization.

Apparently, this is not the case.

RESEARCH METHODOLOGY

As stated above, the Phenomenological approach for evaluating problem based learning using case study, survey and observation were used to carry out the study as it enabled the author to focus on the subject under investigation

The main data collection method used was done through careful observation, interviews and survey.

Three buildings; Building A = one-bedroom bungalow, Building B = three-bedroom bungalow and Building C = three-bedroom bungalow were carefully chosen because they are among the common type of buildings found throughout the country.

Interviews were conducted and measurements carried out. The data collected were graphically presented using tables and analyzed using mathematical formulae to find percentages of spaces properly and not properly illuminated.

THE CONCEPT OF DAYLIGHTING IN BUILDING

The Whole Building Design Guide (WBDG) which is a program of the National Institute of Building Services USA defines Daylighting as a controlled admission of natural light, direct sunlight and diffused skylight, into a building to reduce electric lighting and save energy. A more appropriate definition to fit Nigeria power situation would be , 'Daylighting is the controlled admission of natural light, direct sunlight and diffused skylight, into a building to reduce electric lighting, save energy and to serve as a source of illumination during power cuts and in situations where power is not available.

No daylighting design will save any energy unless the electric lights are turned off when there is sufficient illumination from daylight. Daylighting can be a viable energy-efficient strategy in almost any climate and can also work in all type of buildings.

Windows are the primary vehicles which convey light to the building interior. Windows can be broadly divided into two types. The window set in the side wall of a building and the opening light set into the roof, generally known as Roof lights. The plates 1 and 2 underneath show different ways windows can be set in buildings.

Plate 1; windows on side wall
Source; Author

Plate 2; windows spanning the side wall
Source; Author

Daylighting sources in a building is composed of the following;

- Direct Sunlight: it is characterized by high intensity and constant movement. The brightness of direct sunlight varies by season, time of day, location and sky conditions. The luminance produced on the surface of the earth may exceed

100,000 lux (Reinhart, 2012). Allowing this type of sunlight into the interior must be done with good daylight design.

- Sky Light: this light is characterized by sunlight scattered by the atmosphere and clouds resulting in soft diffuse light. The luminance level produced by an overcast sky may reach 10, 000 lux to 30,000 lux depending on the conditions of the clouds (Reinhart, 2012). This type of light is good for daylighting.
- Reflected Light: this is light (sunlight and sky light) that is reflected from the ground, vegetation, buildings etc. The surface reflectance of the surrounding will influence the total amount of reflected light reaching the building.

All these light sources can have access to building interior through openings as shown in plate 3 below;

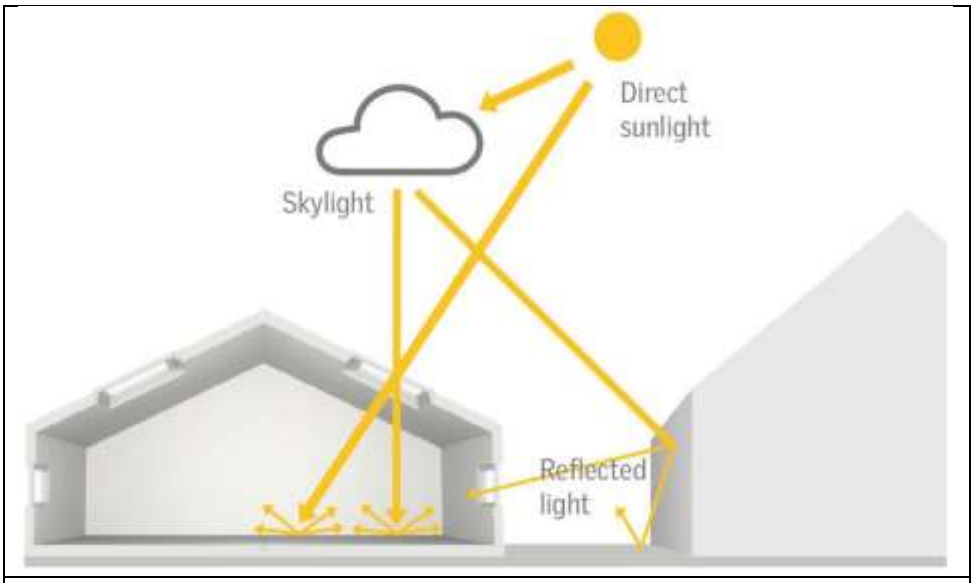


Plate 3; Sources of Daylightlng
Source; Author

The goals of room daylighting are to adequately illuminate visual tasks, create an attractive visual environment, to save electric energy and to provide the light needed for our biological needs (Lam, 1986)

Windows have transparent or translucent glass infill. The solar radiation falling on a window glass surface that is not reflected must be either transmitted or absorbed.

The light that ends up in the building interior can be seen in a solar spectrum broadly divided into three regions; Ultraviolent, Visible and the Infra-red. Only small sections

of the spectrum between 0.4 to 0.76 microns of light are visible to the eye as stated by Givoni in 1981.

HISTORY OF NATURAL LIGHTING IN BUILDINGS.

The history of architecture is synonymous with the history of windows and daylighting. (Philips, 2000). There had been several windows modifications over the years but it primary purpose of admitting light into a building interior remained unchanged.

To modify the external climate, windows need suitable infill. Before the development of glass, various infill materials were used such as thin slab of marble, sheet of mica or oiled paper etc. (Philips, 2000). Glass was discovered in Egypt as early as 3000 BC, however, it use as a window infill material had to wait until the Roman period when small panes of hand-blown glass set in bronze frame were made to span window openings. In the seventeenth century, in England, large panes of glass for larger windows were developed to let in more light.

Vertical windows set into outside walls to let in light were clearly of the first importance and continue to be so today. However, with the introduction of roof lighting the seventeenth century, designers were freed from the constraints of planning the central areas of their buildings.

In the 1930s an entirely new construction methods (modern movement in England) when in residential buildings were made with whole walls of glass and wrap-around windows at corners.

Natural lighting had remained the primary means of lighting buildings until the early twentieth century when designers began to produce buildings with electric lighting as the primary source of lighting. This is well captured in a book written by Derek Phillips in 1964; 'it is inevitable that artificial light must become the primary light source where efficiency of vision is combined with an economic analysis of building function. Natural lighting is becoming a luxury.

The reliance on artificial lighting continued until the realization that fossil fuels for power generation had limitations. This prompted a shift toward daylighting.

DAYLIGHTING IN SOME SELECTED BUILDINGS

The three buildings surveyed are;

Building A = One-bedroom bungalow at No. 15, David Mark Road, Tunga, Minna, Niger State.

Building B = Three-bedroom bungalow at No. 5, Life close, Living water Avenue, Narayi Highcost, Kaduna, Kaduna state and

Building C = Three-bedroom bungalow at No. 3, Kaduna Poly Staff Quarters, Television, Kaduna.

In all the buildings, the floor areas and the sizes of window openings of each room were measured. The occupants were asked to state if the illumination level of each room is sufficiently bright for human activities in such spaces. The following were the data obtained including sketches of the floors;

Building A = One-Bedroom bungalow

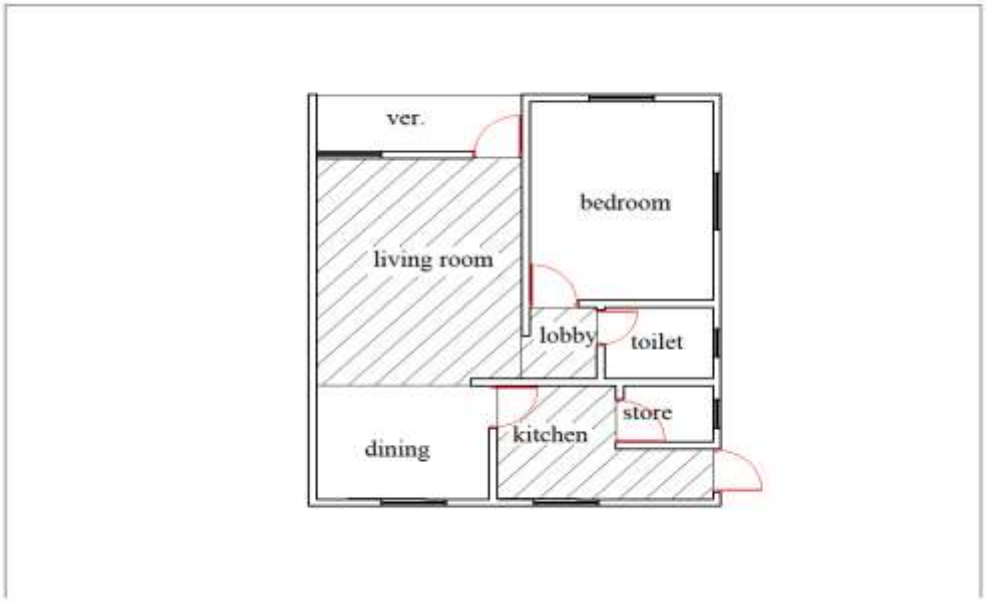


Fig 1: One-Bedroom Bungalow with shaded area adjudged to have insufficient illumination by occupants

Source: Author

Table 1: Data; Building A

Source: Author

S/n	Room	Floor Area (M^2)	Window size (M^2)	% of Window to Floor Area	Bright Enough?
1	**Living Room**	**17.67**	**1.44**	**8.15**	**No**
2	**Dining**	**7.68**	**1.44**	**18.75**	**Yes**
3	**Bedroom**	**14.28**	**2.88**	**20.19**	**Yes**
4	**Kitchen**	**7.17**	**1.44**	**20.80**	**No**
5	**Store**	**1.98**	**0.36**	**18.18**	**Yes**

6	**Toilet**	**3.00**	**0.36**	**12.00**	**Yes**
7	**Lobby**	**1.80**	**1.89**	**105**	**No**

Percentage of floor area with good illumination =
Sum of floor area with good illumination X 100%
Total floor area
= 26.94 X 100% = 50.28%
53.58

Percentage of floor area with poor illumination =
Sum of floor area with poor illumination X 100%
Total floor area
= 26.64 X 100% = 49.72%
53.58

Building B =Three-Bedroom bungalow

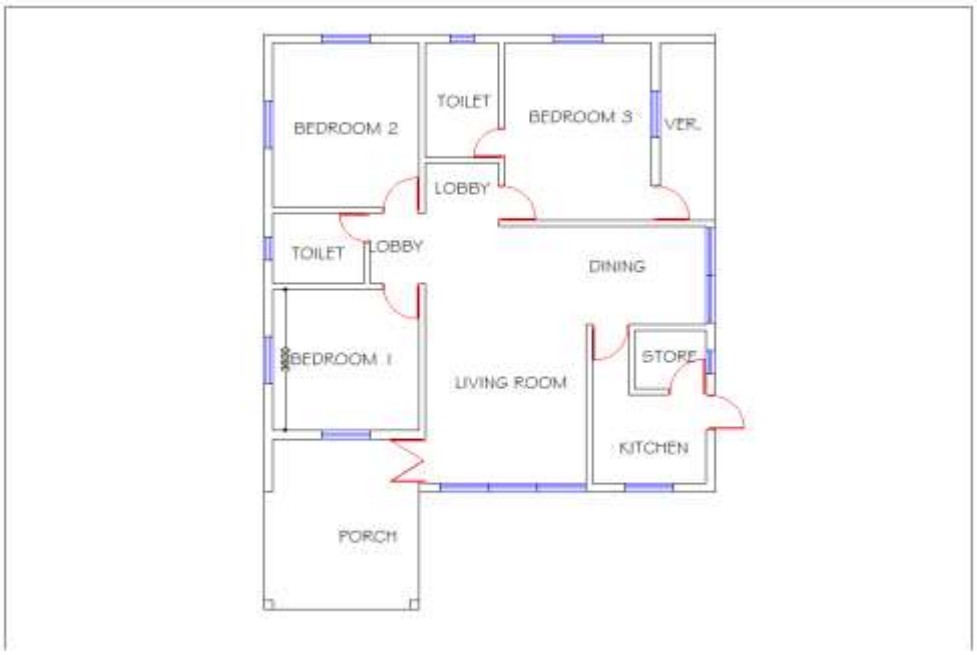


Fig 2: Three-Bedroom Bungalow with un-shaded area adjudged to have sufficient illumination by occupants
Source: Author

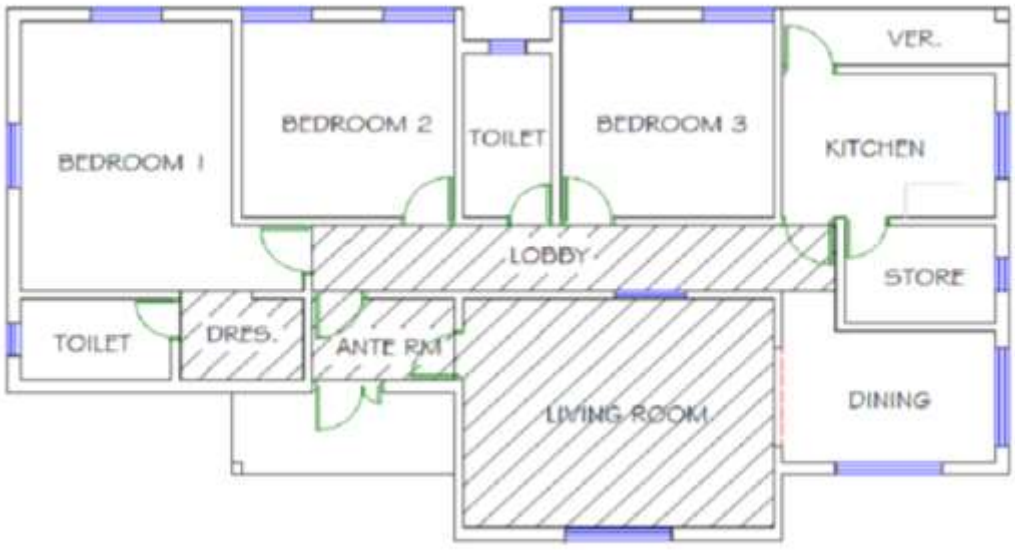
Table 2: Data; Building B

S/n	Room	Floor Area (M^2)	Window size (M^2)	% of Window to Floor Area	Bright Enough?
1	Bedroom 1	12.96	2.88	22.22	Yes
2	Bedroom 2	15.12	2.88	19.05	Yes
3	Bedroom 3	16.20	2.88	17.78	Yes
4	Living Room	25.90	4.32	16.68	Yes
5	Dining	9.88	2.88	29.15	Yes
6	Toilets	9.32	0-72	7.75	Yes
7	Lobbies	4.72	3.24	68.64	Yes
8	Kitchen	7.94	1.44	18.14	Yes
9	Store	2.63	0.36	13.69	Yes

Source: Author

Percentage of floor area with good illumination =
Sum of floor area with good illumination X 100%
Total floor area
= 104.67 X 100% = 100%
104.67

Percentage of floor area with poor illumination =
Sum of floor area with poor illumination X 100%
Total floor area
= 0.00 X 100% = 0.00%
104.67



Building C =Three-Bedroom bungalow

Fig 3: Three-Bedroom Bungalow with shaded area adjudged to have insufficient illumination by occupants

Source: Author

Table 3: Data; Building C

S/n	Room	Floor Area (M^2)	Window size (M^2)	% of Window to Floor Area	Bright Enough?
1	**Ante Room**	**3.60**	**0.00**	**0.00**	**No**
2	**Living Room**	**22.00**	**2.16**	**9.82**	**No**
3	**Dining**	**8.64**	**4.32**	**50.00**	**Yes**
4	**Lobby**	**10.62**	**0.00**	**0.00**	**No**
5	**Store**	**4.05**	**0.36**	**8.89**	**Yes**
6	**Kitchen**	**9.36**	**1.44**	**15.38**	**Yes**
7	**Bedroom 1**	**18.00**	**2.88**	**16.00**	**Yes**
8	**Bedroom 2**	**12.96**	**2.88**	**22.22**	**Yes**
9	**Bedroom 3**	**12.96**	**2.88**	**22.22**	**Yes**
10	**Toilets**	**8.33**	**0.72**	**8.64**	**Yes**
11	**Dressing**	**3.15**	**1.89**	**60.00**	**No**

Source: Author

Percentage of floor area with good illumination =
Sum of floor area with good illumination X 100%
Total floor area
= 74.30 X 100% = 65.36%
113.67

Percentage of floor area with poor illumination =
Sum of floor area with poor illumination X 100%
Total floor area
= 39.37 X 100% = 34.64%
113.67

DISCUSSION

It can be seen from the analysis above that the percentages of floor areas with good illumination levels are above average in the three buildings studied. The author would be specific to drive home some points.

BUILDING A

Living Room- Areas behind the opaque door and deep into the room are poorly lit. Though, the area close to the window has good illumination.
Lobby- The window to floor area ratio is high yet little natural light reach the lobby. This is largely because of the way the opening is placed in respect to the source of light.
Kitchen-Area close to the exit door is also poorly lit because the reflected and diffused light reaching the space is not strong to cause the desire effect.
Electric lighting would have to be used if proper lighting is required in certain spaces.

BUILDING B

All the spaces in this building have good illumination levels making it possible to have a zero electric lighting in the daytime.

BUILDING C

Dressing- There is no window opening in the dressing. It was adjudged to be poorly illuminated.
Lobby- the long lobby connects all the spaces together yet not properly lit. The only source is from one opening which is not adequate.
Electric lighting would be needed to supplement daylighting in some spaces.

INFERENCE

The percentage of window size to floor area is important. Space with a low percentage of 7.75 is considered as having good illumination.
It could also be inferred that the percentage of window size to floor area is not the only consideration. The lobby in Building A has the highest percentage of 105 yet it is adjudged to be poorly lit. The position of the opening in relation to the source of light is also important.
Also from the data collected, spaces with windows on adjacent walls are better illuminated.

SOLUTIONS

The following design and construction methods and techniques if properly used would solve the problem of poor daylighting observed.

- Window Location and Size
  Simple side lighting strategy allows daylight to enter a space. The depth of daylighting penetration is about two and one half times the distance between the top of a window and the sill according to Whole Building Design Guide (WBDG), National Institute of Building Services USA. Increasing the window

size and strategically positioning would be good solution in some of the problems raised above.

- Reflectance of Room Surface
  Room surface with good reflectance value would have significantly impacted on daylighting performance and should have been employed in some of the spaces with poor illumination levels
- Rooflights
  In certain spaces, especially in deep-planned buildings, daylighting using side wall is almost impossible. In such spaces, like the lobby in Building C, rooflighting would have been a good option.
  Rooflighting permits daylight to enter a building from above through a glazed opening in the roof protecting the interior from wind and weather. A simple form is the use of a translucent roof sheet and ceiling material at points where illumination is needed in the building.

  Other forms of rooflight include Dome (glazed) see plate 4 below, Shed roof, Sawtooth roof, Monitor and Atrium roofs.

Plate 3; Shopping centre in Leeds showing Vaulted Rooflight
Source; Derek Phillips

- **Light Pipes**

This is a very simple and effective method of transporting daylight into a building like the long lobby in Building C. The Light Pipes rooflighting which by means of association with reflectance tubes directs light to a lower level. It can be employed to convey light through several floors.

CONCLUSION

There is Hausa adage that properly summaries this research work; '*Rashin sani kaza ta kwana a dami da yunwa*' meaning suffering where one should have be in affluent because of inadequate knowledge to utilize resources to one's benefit.

Certainly, the conclusion of this research is that all buildings can have zero electric lighting during the day by employing proper daylighting techniques given the abundant solar radiation across Nigeria throughout the year.

Hence, there must be a shift to utilize daylighting methods that are efficient and effective.

RECOMMENDATION

To achieve zero electric lighting during the day, regulatory bodies must work together to set national minimum standards for daylighting requirements and ensure it enforcement. Surely, without any apology, we must work together to keep the environment green.

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