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RESEARCH ARTICLE

THE IMPACT OF DAYLIGHTING IN THE DEVELOPMENT OF SUSTAINABLE ELECTRIC POWER AND BUILDING INFRASTRUCTURES IN NIGERIA.

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ABSTRACT

Electricity supply as a critical economic infrastructural facility is indispensable to a nation's economic development. Nigeria is presently faced with the problem of inadequate power supply; which has led to the closure of many industries and concomitant unemployment and a battered economy. The country's electrical power demand is high but actual generation is considerably below demand. As a result Nigeria has experienced power supply crisis in recent years. The power sector privatization of Power Holding Company of Nigeria (PHCN) is geared towards further development of a sustainable electric power infrastructure to curtail the crisis. The use of daylighting by consumers to reduce electrical power demand was investigated as a sustainable approach for energy optimisation. Considering that 30% of global electricity consumption is attributed to lighting, savings in electricity consumption due to lighting will be channeled to industrial use; hence the re-opening of some of the industries and generating employment. Also using the daylighting component in architectural design for buildings and the optimal use of daylighting for indoor and outdoor electrical lightings would assure the desirable sustainable electricity power supply in a developing economy. The saving of 4MW of power on street lighting alone within the University of Jos community was achieved using daylighting.

KEYWORDS: - Daylighting, Facility, Optimal, Privatization, Infrastructure, Sustainable.

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INTRODUCTION

The Nigerian economy has been bedeviled by a serious power supply crises, as unreliable power supply constitutes a major challenge to Nigeria's economic growth and development. Erratic and unpredictable nature of electricity supply has resulted into the closure of many industries translating into the loss of several jobs in a developing economy. According to Darling *et al* (2008)

for many years now, Nigeria has been facing an extreme electricity shortage. This deficiency is multi-faceted, with issues that are financial, structural and socio-political, none of which is mutually exclusive. Today, Nigeria has probably the biggest gap in the world between electricity demand and supply, providing its population of over 150 million with roughly 4000MW of electricity, though Nigeria hit historical highs for both peak generation (4,811MW peak generation) and total energy generated across the system (4,213MWh/h energy generated) in August 2015 (APT, 2015). In contrast South Africa generates more than 40,000 MW for a population of 47million while Brazil generates more than 100,000MW for its population of 201 million citizens (Lagos Oil Club, 2012). Due to lack of reliable electricity, many households and Companies supplement the electricity provided by the grid system with their own generators. In fact; almost everyone who can afford a generator owns one. According to approximation, well over 90% of businesses have generators (Darling *et al*, 2008). PHCN's deficiencies are prevalent throughout the power system, both upstream and downstream. For example, with modern technology about 40% of energy consumed in thermal plants can be converted to electrical energy.

The Nigerian electric networks operate below its capacity of 5900MW, and power outages remain unabated (Akinwale, 2010). According to Biodun (2011) there is a positive impact from the power sector on the industrial development of Nigeria. Also alternative energy source for the production of electricity is vital for effective supply of electricity in Nigeria through various renewable energy sources. The Nigerian overall consumption per capita is about 126Kwh, Ghana's per capita consumption (361kWh) is 2.9 times higher than that of Nigeria, and South Africa's (3,926kWh) is 31 times higher. Contrary to the Nigeria Government plan in 2003 to expand electricity access to 85% of the population by 2010, only 40% of Nigerians have been able to access electricity. Despite changes in the Nigerian electricity sector, the poverty of energy is entrenched in the country; about 85 million people representing approximately 60% of the population lack access to electricity services. Total electricity production in Nigeria was estimated in 2007 to be 23.11Kwh, yet electricity consumption is only 16.25Kwh (IEA) The previous government in its attempt to increase power generation to a reasonable level by 2015 had carried out the privatization of the Power Holding company of Nigeria (PHCN) Through privatization, the government was aiming at increasing electricity supply from about 4000MW to 6000 by the end of the year. According to Osobase and Bakare (2014), it has been observed that, irregular electricity supply has been a major bane to output growth in the manufacturing sector; therefore, it is recommended that the power sector by means of guided private sector initiative should be given more attention for the growth of the nation's economy.

Solving the Nigerian power supply crises cannot be achieved by generation of more Mega Watts alone, transmission, distribution, utilization and architectural building designs are some other factors to consider. Considering that 30% of global electricity consumption is attributed to lighting, savings due to lighting is considered an important factor in solving the Nigeria's power supply crises. According to US Department of Energy's Federal Energy management Program, savings from daylight can cut lighting energy use by up to 75-80%. In terms of cost savings the Department of Energy reported that many commercial buildings can reduce total energy costs by up to one-third through the optimal use of day lighting. Architectural design of buildings is another area of power saving if design for day lighting is considered by the architect at the earliest stages of

building. According to an IEA study (IEA, 2006), global grid based electricity consumption for lighting was about 2650 TWh in 2005, which was an equivalent of 19% of total global electricity consumption. European office buildings dedicate about 50% of their electricity for lighting, whereas the share of electricity for lighting is around 20-30% in hospitals, 15% in factories, 10-15% in schools and 10% in residential buildings (EC, 2007). Day light reduces energy consumption by replacing electric light with natural lights. This is suggesting a new approach of consumers using daylighting to reduce electrical power demand.

What is Light?

Light is a form of energy manifesting itself as electromagnetic radiation and is closely related to other forms of electromagnetic radiation such as radio waves, radar, microwaves, infrared and ultraviolet radiation and X-rays. The only difference between the several forms of radiation is in their wavelength. Radiation with a wavelength between 380 and 780 nanometres as shown in figure 1 forms the visible part of the electromagnetic spectrum, and is therefore referred to as light.



Figure1: Visible spectrum

Concept of Daylighting

“Daylighting” refers to the use of sunlight, skylight, and overcast sky illumination to provide functional interior lighting that is appropriate to specific programmatic areas and comfortable to the occupant. When daylight is used as part of an integrated design strategy it can provide substantial energy savings. The overall objective of daylighting is to minimize the amount of artificial light and to reduce electricity consumption and lower HVAC costs (Sharaf, 2014) Daylighting offers the potential for highly productive work environments that also save energy. According to Thermie (1994) artificial lighting is a substantial consumer of energy in non-domestic buildings. In offices it can account for as much as 50% of electricity consumption, and if the building has a deep plan it may use more energy than the heating does. Artificial lighting must be installed in most buildings to provide lighting after dark and on cloudy days. Most commercial buildings are designed with lighting systems that draw between 1 and 2 watts per square foot of floor space. These systems are often operated all day regardless of how bright it is

outdoors. Using natural sunlight for inside lighting can substantially reduce energy consumption of daytime lighting requirements. The practice of using natural light to replace artificial lighting is called “daylighting” or sometimes “daylight harvesting”. While it might seem simple to add openings in the roof or walls, an effective daylighting design requires careful consideration of several factors, all of which are crucial to achieving the expected energy savings. According to Kroelinger (2005) Daylight can provide a welcome and dynamic contribution to the human experience in buildings and, as demonstrated in recent studies on schools and retail sales environments, can impact human performance. Most people appreciate daylight and also enjoy the outside view that windows provide. Good daylighting design can result in energy savings and can shift peak electrical demand during afternoon hours when daylight availability levels and utility rates are high.

Daylighting is the controlled admission of natural light; direct sunlight and diffuse skylight—into a building to reduce electric lighting and saving energy. By providing a direct link to the dynamic and perpetually evolving patterns of outdoor illumination, daylighting helps create a visually stimulating and productive environment for building occupants, while reducing as much as one-third of total building energy costs (Ander, 2014). According to Edward (2005) Daylight is superior to electric light sources in the measure of light source efficiency. Beyond the simple conclusion that well-designed daylighting can reduce electric energy use in libraries, there are two additional traits of daylighting that make its use compelling. The first important fact is that the efficacy numbers are based on energy used at the building. If the total energy used to generate the electric power was accounted for, the electric light fixtures would have a dramatically lower efficacy. To create electric power at the electric generation plant, fuel is burned to drive turbines and about two-thirds of that energy is lost to the surrounding atmosphere in the form of heat. Only about one-third of that energy arrives at the building site in the form of electric energy, assuming the transmission losses are small. The second important fact about daylighting versus electric lighting, namely that daylighting energy is locally available at the site and it is renewable Daylighting design is therefore an important component of sustainable (green) design of buildings.

Objective

The objective of this paper is to

- i. Present the energy saving achieved as a result of the use of daylighting.
- ii. The impact of architectural design of building infrastructure with daylighting provision having a significant impact on electric power consumption.

MATERIALS AND METHODS

This paper considers daylight hours (day length) which is the number of hours between sunrise and sunset in Jos, the capital of plateau state, Nigeria with coordinates $9^{\circ}55'00''$ N, $8^{\circ}54'00''$ E for January 2013 to December 2013.

Daylight Hours for Jos

There are several methods of calculating daylight hours the trigonometric functions and graphical method, just to mention few. As shown in equation (1) the hours of daylight on a particular day of

the year are a piece of data that repeats every year so should be able to be modeled by a trigonometric function. Leslie (2012) used a function of the form

$$H = A \sin (Bt - C) + D \dots \dots \dots (1)$$

where t is the day of the year and H is the number of daylight hours, A is the amplitude of the sinusoidal wave, B is the frequency, C is the phase shift and D is the vertical displacement.

According to Hafer (2013) a graphical method for calculating daylight hours uses a side view of the Earth with the parallels and the circle of illumination illustrated. This view is at the Summer Solstice. Measure the linear length of a chosen parallel, L, and the distance along the parallel from the sun side to the circle of illumination, D, then, apply these lengths to equation (2):

$$\text{Daylight hours} = \left(\frac{(2 \cdot \sin^{-1}(2 \frac{D}{L} - 1)) + 180}{360} \right) \times 24 \dots \dots \dots (2)$$

The recorded daylighting hours for Jos for the months of January to December 2013 are shown in Figure 2.

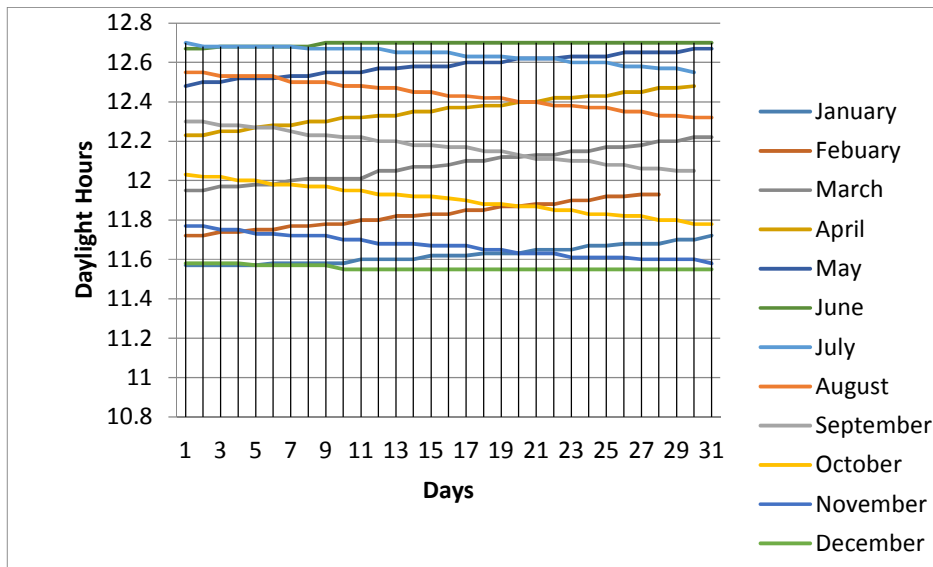


Figure 2: Daylighting Hours for Jos (2013)

From figure 2 it can be seen that the maximum daylight hours of 12.70 hours was from 11/6/2013 to 31/6/2013. The minimum daylight hour of 11.55 hours was from 11/12/2013 to 31/12/2013. The maximum and minimum daylight hours are observed to be exactly six months apart.

Daylighting and Architecture

According to Phillips (2000) Vision is the main role of lighting architecture. Before the appearance of electrical lighting, building design responded to the climatic parameters and daylight conditions

of a place in order to achieve adequate lighting levels in the interior for visual performance. “It is light that can make a building bright and airy or dull and gloomy”. Daylighting can contribute immensely in the saving of electrical power in buildings because the electrical power that would be consumed in Cathedrals like Gothic Cathedral can better be imagine. According to Abdulsalam *et al.* (2014) introducing natural light into buildings saves energy and also creates an attractive environment that improves the well-being of its occupants. The provision of effective daylight in buildings can be assessed using average daylight factors and by ensuring that occupants have a view of the sky. The average daylight factor will be influenced by the size and area of windows in relation to the room, the light transmittance of the glass, the brightness and colour of the internal surfaces and finishes, the depth of reveals, and the presence of overhangs and other external obstructions which may restrict the amount of day lighting entering the room. Chan and Tzempelikos (2015) in their findings pointed out that the integrated thermal and daylighting model shows the benefits of multifunctional façade concepts. The most significant benefit comes from lighting energy savings, also associated with the reduction of cooling load due to the decrease in internal heat gain. A typical daylighting architectural design is shown in Figure 3.



Figure 3: Typical Daylighting Architectural Design.

Daylighting and Energy.

The use of natural lighting buildings has many implications for the energy use in buildings. A reduction in the energy consumption of commercial and public buildings can be attained by decreasing the need, or use of artificial light. For example, at a given level of illumination a tungsten light produces between 5 and 14 times heat than daylight (Baker and Steemers, 2000) as a consequence daylight also lowers cooling requirements of a building up to 15% (Muhs, 2000). According to Thermie (1994) artificial lighting is a substantial consumer of energy in non-domestic buildings. In offices it can account for as much as 50% of electricity consumption, and

if the building has a deep plan it may use more energy than the heating does. There are not many non-domestic buildings in which daylight can meet all lighting requirements, even during daylight hours; but equally there are few building types in which it cannot make a substantial contribution. In hospitals 20% - 30% of electricity use may be attributed to lighting; in factories typically 15%; in schools 10% - 15%. This does not mean that energy savings related to lighting are less worthwhile in these building types than in offices. According to Demir and Konan (2013) Economic benefits of using natural lighting should not be ignored. More recently, daylighting has been advocated as a way to reduce lighting energy use in schools and other non-residential buildings. Turning off electric lights when sufficient daylight is available can save a significant amount of lighting energy costs. Because daylight introduces less heat into a building than the equivalent amount of electric light, cooling costs can also be reduced with appropriate daylight design. Decreasing the 40% to 60% of power going to electric lighting is the first cost saving. Daylighting, with less waste heat from lights, can also contribute up to 20% to energy savings due to decreased cooling loads in schools with air conditioning. Nearly 60% of electricity production comes from the burning of coal and its attendant emission of carbon. Every watt of energy saved reduces the amount of carbon emissions released into atmosphere. Daylight provides its benefits during daytime, when the demand for electricity is at its peak. Reducing energy usage during the day reduces the strain on the electricity grid infrastructure. Saving on the costs of energy arise interest of school administrators. This way the costs of energy can be saved and used for educational purposes.

Daylighting for Indoor and Outdoor Electrical lighting

According to Kappia (2009) interior or indoor lighting is the one in our house which represents 25% of energy consumption, this is in houses, schools, hospitals shops, hotels, industries e.t.c. External or outdoor lighting is the one that is on streets and avenues and represents 2 and 5% of the electrical energy consumption of the Country. Outdoor and Indoor energy efficient lighting is very relevant now in view of the prevailing power crises in Nigeria. Odufuwa (2009) pointed out that there is no gain saying that if energy efficient concept is adopted and utilized in our buildings it would ameliorate the prevalent energy crises.

The University of Jos has lecture Theaters and Halls in its three Campuses the present Theaters and Halls are a serious source of energy consumption seeing that getting them properly lighted will cost millions of Naira, not to mention the power consumption. Efforts have been made to reduce power by using efficient bulbs, but daylighting is proposed as a more reliable and economic method. The multipurpose auditorium (Theater) may be reroofed to use daylight as an energy saving source, the initial cost of reroofing may be high but the payback period will be very short. A proposal is as shown in figure 4.



Figure 4: Daylighting proposal for multipurpose auditorium

Daylighting and Electrical lighting of Security lights.

Using electricity to light street lights is the commonest thing in the cities and University campuses. The Village Hostel, University of Jos operates over 324 street lighting points, 250W per lamp. The lights are operated using manual switches. The manual switch ON and OFF of Lamps results most of the time to the lamps being ON throughout the day. The energy consumed per hour for the street lights alone is 81KW every hour and for 24 hours, energy consumed is 1.944 MW. The use of daylighting technique for the street lights has help to reduce the operating hours of the street lights by 12hours on the average. Photocells were incorporated to control the lights and also, delay timers introduced to ensure proper light up. Photocells turn off electric lighting in areas where large amounts of natural daylight are present. Photocells use light sensitive cells similar to solar panels to detect sunlight. When a prescribed amount of natural light is available, they turn off electric lighting in the area. The power consumption on the University feeder was reduced by about half, on the billing it was observed that about 4MW of power was saved, which can be channeled for other use.

Benefits of Daylighting

Daylighting has several other benefits apart from savings in electrical power among some of the benefits are:

* Daylighting reduces energy consumption by replacing electric light with natural light, reducing electricity bill.

*Makes available energy to provide supply to the remaining population

*It limits and reduces the environmental impacts and hazards to human health of current energy use.

*It increases the resilience and efficiency of our economy.

* It reduces greenhouse gas emissions associated with fossil fuel sources used to generate electricity.

*It postpones the building of new power plants, and frees up capital for other investments.

CONCLUSION/ RECOMMENDATIONS

The use of daylighting as seen from the case of University of Jos led to saving 4MW of power in street lighting alone; it is just one out of more than 36 federal Universities in the country, if others will do same more power will be saved for our industries to start working. The task of power saving using daylighting is a team work in the construction industry that will involve other key players like the architects and builders. Consumers of electricity should be synthesized as regards the use of daylighting as they plan to build new hospitals, schools, industries and houses so that daylighting will be factored in the planning. If some of these findings and observations are taken seriously Nigeria's present power crises will to a large extent be reduced substantially even if new generation stations are not build in the next few years. It is worthy of note that daylighting is a sustainable renewable energy and to a large extent has abundant resources to be tapped.

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