International Journal of Technology (2016) 1: 15-25
ISSN 2086-9614

ENERGY PERFORMANCE INDICES FOR HOSPITAL BUILDINGS IN NIGERIA

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(Received: September 2015 / Revised: January 2016 / Accepted: January 2016)

ABSTRACT

In Nigeria, the economic problem of allocating energy to medicare have long been a major concern and standardized indices to be used as guidance are non-existent. This paper determines energy indices for assessment of how Nigerian hospitals prioritize their energy utilization. Systematic field surveys followed by in-depth statistical analysis were adopted. The hospitals were stratified into four categories for the investigation. Then, questionnaires were designed, randomly administered and their responses generated in conversation with workers at 70 hospitals in Nigeria. Results of the analysis show that an average hospital in Nigeria, depending on its category, uses energy as follows: rural 66.936kWh/day; urban 343.23 kWh/day; specialist 454.872 kWh/day and teaching 1,944.394 kWh/day. Lighting is shown as a critical energy function and accounts for as much as 15%, 36%, 40.5% and 69.5% of daily energy use in rural, urban, specialist and teaching hospitals, respectively. A productivity based energy performance indicator for each hospital category works out to be 3.346 kWh/bed space/day, 2.367 kWh/bed space/day, 4.548 kWh/bed space/day and 19.443 kWh/bed space/day, respectively, for typical rural, urban, specialist and teaching hospitals. The respective Building Energy Index (BEI) values for the categories of hospitals are as follows: rural 0.13 kWh/m^2/day; urban 0.077 kWh/m^2/day; specialist 0.088 kWh/m^2/day and teaching 0.277 kWh/m^2/day. The low BEI implies that the buildings have lower rates of sick building syndrome symptoms. Also, auto-generation is predominantly used in all the hospitals, when grid utility supply is unavailable.

Keywords: Building energy index; Energy performance; Hospital building; Lighting energy indicator; Nigeria

1. INTRODUCTION

In Nigeria, effective healthcare delivery service is a very important and desirable social service. Efficient healthcare service delivery is heavily dependent on reliable and adequate power supply (Nwanya & Ekechukwu, 2013). Previous studies have indeed established a strong dependence of health services on energy (World Health Organization, WHO, 2013; Al-Karaghouli & Kazmerski, 2010; Jimenez & Olson, 1998). Most hospital equipment and services depend largely on a reliable power supply (Bosch & Glaser, 2012). Preservation of a wide variety of drugs, blood and other tissue samples in refrigerators, sterilization of surgical devices, water purification, lighting and thermal comfort for patients and staff, to mention but a

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Permalink/DOI: http://dx.doi.org/10.14716/ijtech.v7i1.2094

few, depend entirely on regular electricity supply, such that disruptions in power supply, generally, adversely affect treatment schedules (Gordo, 2011; Hu et al., 2004).

In many parts of Nigeria (as indeed in most developing countries of the world), grid-connected electricity supply is unreliable and in most remote rural locations particularly, frequently unavailable. Alternative fossil fuel sources of electricity generation are, for these locations, prohibitive. In Nigeria, most of the hospitals depend on alternative gasoline or diesel fuelled power generating sets. Consequently, a high proportion of the operating cost of hospitals and consequently patients' bill are related to energy. Thus, for most of the hospitals, particularly those in rural locations, the actualization of the critical efficient and effective healthcare delivery is very adversely affected, (Nwanya & Ekechukwu, 2013). Under such conditions, renewable energy systems, e.g. capacity-based autarkic photovoltaic systems have become increasingly attractive as viable alternatives. However, the critical energy performance parameters for allocating energy to medical care and monitoring how the hospital uses its energy supply are non-existent. With that view, factual reflection of energy content in and equitable costing of medical services are some of the significant advantages of calculating the energy performance indicators. Hence, energy performance indicators are specific metrics that account for how well the energy plan is working relative to focused level of activities.

Several studies have been conducted on energy performance of hospital buildings (Pinzone et al., 2012; Stankovic et al., 2009). It has been recognized that achieving an appreciable level of performance is capital cost intensive, (Degelman & Soebarto, 2013). In addition, hospital buildings are usually complex facilities, with a variety of energy functions, as shown in Figure 1. These facilities operate continuously for 24 hours a day, seven days a week and the intensity of the energy needs grows linearly during that duration of service.

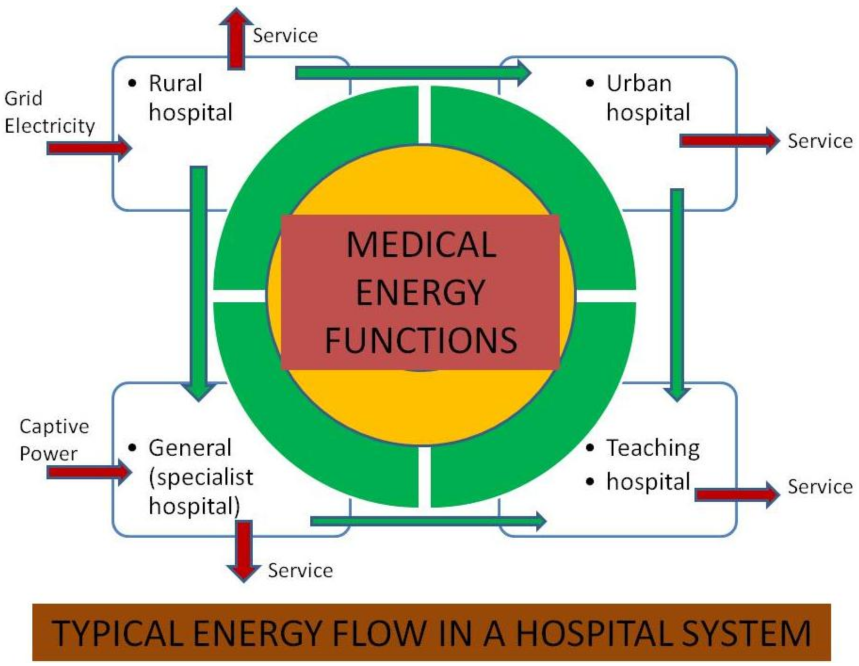

Figure 1 A model hospital complex with a wide variety of energy functions

A number of factors that influence hospital energy use intensity, such as facility size, climate, weather, operating schedule and the suite of activities, have been discussed (Singer et al., 2009). At the same level of energy consumption, indoor air quality can be affected (Seppanen, 2008). Since the variability in energy use is almost certainly due to these factors, there is a need to use energy metrics to measure specific performance targets at the level of the hospital facility. The methodology for the determination of the energy performance of buildings is well-documented (CEN/TC 169 N 0618, 2013). In addition, Chen (2009) reviewed the tools for predicting performance in hospital buildings. The interest in hospital buildings is because of a wide variety of energy uses (Perez-Lombard et al., 2008). and it represents one of the main types of buildings having great potential to apply measures of energy savings (Life04 EMV, 2013). By increasing energy efficiency, hospitals can improve the bottom line and free up funds to invest in new technologies and improve patient care (Yildiz, 2011; US Energy Information Administration, 2010) However, the authors are not aware of anywhere in the literature that hospital energy performance appraisals were carried out in relation to time, energy and capacity simultaneously. The conventional hospital capacity measurement by bedspace alone is erroneous.

The main purpose of this study is the determination of some of the energy performance indicators for the assessment of hospital energy utilization. To achieve these identifiable targets, the specific objectives include: to estimate some of the energy performance indices in hospital buildings; to determine the quantities of energy usage and their consumption patterns within the hospital location and to compare the usage of lighting facilities in hospital buildings with a view to planning for energy efficient measures. In that way, this research paper bridges the gap between allocating energy to medical care and monitoring how energy requirements are prioritized in hospital facilities. This type of monitoring is important for measuring productivity.

The study focused on energy consumption of four categories of hospitals identified in Nigeria. The results are most significant to decision makers as a helpful tool to monitor and evaluate the fitness for use of the hospital buildings for cost-effective service delivery.

2. METHODOLOGY

The study adopted a systematic field survey followed by a detailed statistical analysis of the ensuing survey results. For the field survey, the hospitals were stratified into four categories:

- Rural Hospitals (R)
  These are involved mainly with primary care and ambulatory services and are owned predominantly by private proprietors (a few are public local government clinics). Patient clientelle are largely from the host community.
- Urban Hospitals (U)
  These are more comprehensive health systems offering primary and secondary healthcare services and are owned by regional governments, missionary or private proprietors.
- Specialist Hospitals (S)
  These are centers of integrated health system offering, in addition, tertiary specialist healthcare services and are owned predominantly by federal and regional governments.
- Teaching Hospitals (T)
  These are principally for teaching and research and are also integrated health system centers, offering tertiary specialist healthcare services and are owned predominantly by federal and regional governments (a few privately owned university teaching hospitals exist). However, the number of registered hospitals in Nigeria is 6,982. In the above figure, Teaching and Specialist (Federal Medical Centres) hospitals are known for their distinct ownership structure and number 19 and 20, respectively. Rural and Urban hospital categories were not listed accordingly by the Federal Ministry of Health.

To establish a measurement criteria for energy use that was analyzed for the energy performance assessment, a walk-through energy audit approach was undertaken. Energy audit questions designed to obtained performance measures were used and responses to them were generated in conversation with hospital workers. This was carried out for four representative hospitals to obtain their historical energy consumption using data from utility bills, plant/equipment records and patient turnover during 2013. The hospitals considered for this study are located within 400 kilometers from the University of Nigeria Nsukka for easy coordination of data and logistics. Also, the area of each representative hospital is 515, 4458, 5170 and 7020 square meters, respectively for R, U, S and T categories.The energy performance assessment covered all services of the hospital, including lighting, ventilation and cooling. An inventory of all types of medical equipment used and their power ratings were taken as reference base to the energy requirement assessment.

The primary data collection utilized, as an instrument, a structured and pre-tested questionnaire. The survey questionnaire sought information on operating characteristics of hospital buildings, such as gross internal floor area (m^2), on-time (hours), bed space, thermal characteristics of medical equipment (power rating), lighting, ventilation, air-conditioning and refrigeration facilities, in addition to patient census and energy consumption values for the buildings. The questionnaires were administered randomly to 70 hospitals in Nigeria. However, the implementation of the survey plan was difficult because of insufficient information, which can be traced to a lack of bookkeeping of energy data.

To calculate the energy performance metrics, the data gathered were collated according to each category of hospital by type of service. The significance of this approach is that the amount of power used daily to operate equipment will influence the choice of energy supply source to the hospital. The starting point for the energy performance calculation is energy use information from utility and fuel bills (Hu et al., 2004). These records are stratified into costs and amount of each type of energy used on daily basis. The former is summed into monthly values. Then, the energy consumption, regardless of source, are expressed in a uniform unit, kWh. Finally, full analysis of consumption for each fuel and utility type with costs and operating conditions is carried out based on total energy requirements.

In order to relate results of this study to existing benchmarks, some energy metrics were calculated. In the first stage, summation (X) of all energy consumed for lighting, water pumping, equipment/ appliance operation, ventilation/cooling and refrigeration/ sterilization is obtained. The general expression for X is as follows in Equation 1:

$$X = \sum_{i=1}^{n} (X_{grid} + X_{gen} + X_{ren})_i \quad (1)$$

where i is the individual hospital energy demand from, grid is the grid electricity, gen is the self-generated electricity from generator, and ren is the self-generated from renewable energies/solar photovoltaics and n = number of energy functions applicable to a hospital.

It is also possible to disaggregate bulk demand into components, such as lighting and equipment applications in order to take into account variable energy demand. An estimate of the lighting energy for illumination is calculated as follows in Equation 2 (Stankovic et al., 2009):

$$L_{l,t} = \sum \{(P_n \times F_c) \times [(t_D \times F_o \times F_D) + (t_N \times F_o)]\} / (1000) \, [\text{kWh}] \quad (2)$$

where $L_{l,t}$ is the total energy for illumination function per hospital (including incandescent and compact/fluorescent), P_n is the total installed lighting power in the building in W, F_c is the illuminance factor, t_D is the daylight time usage, F_o is the occupancy factor, F_D is the daylight dependency factor, t_N is the non-daylight usage and t is the time period in hours. In this study, t_D = 0 (for conservation reasons), F_o = 1, F_c = 1 (no illuminance control). For equipment application, the expression is as calculated in Equation 3:

$$Q_e = \sum_{1}^{n} W/_{1000} \times DOH \times operation / year \quad (3)$$

where Q_e is the energy supplied, W is equal to watts, DOH is the daily operating hours. Energy demand per hospital bed space per day can be calculated using Equation 4.

$$M = \frac{\sum FX}{\sum F} \quad (4)$$

where M is the mean energy demand per bed space/day, (kWh/day), X is the energy demand/day, F is the number of bed spaces.

3. RESULTS AND DISCUSSION

A walk-through energy audit carried out for Nigerian hospitals showed different energy supply sources and end uses. Major energy services, such as lighting, ventilation, communication, water pumping and operation of medical equipment were investigated in the respective hospital categories. In addition, information on the patient population, manpower requirements and building parameters were among the responses obtained from the 70 hospitals randomly sampled. Major performance indicators considered include the building energy index, lighting energy numeric indicators, energy use per bedspace per day and energy use performance factors (efficacy). The extent of service we can derive from a given amount of energy supply to a hospital building determines the performance level.

Cross-sectional analysis was carried out on the field data responses, which showed that all the urban, specialist and teaching hospitals rely on the national grid and fossil fuels (generators) for electricity. Sometimes, fuelwood and kerosene are used as alternatives to the national grid in rural hospitals for heating and sterilization purposes. Photovoltaic energy is sparingly used for lighting and storage, although a strong awareness about its potential for energy savings exists among the hospitals. Table 1 shows the estimated consumption for the four hospital categories.

The facts used to reach a decision on the energy performance of hospital buildings are based on energy consumption by end use in Nigeria. Results analysis for the representative rural, urban, specialist and teaching hospitals showed a significant pattern of energy end-uses. For example, the hospital categories under study in Nigeria energy use was as follows: Rural - 66.936 kWh/day, Urban - 343.23 kWh/day, Specialist - 454.872 kWh/day, and Teaching - 1944.394 kWh/day. A descriptive interpretation for the aforementioned energy requirements is that 2.4%, 12.2%, 16.2% and 69.2% are consumed daily by Rural, Urban, Specialist and Teaching hospitals, respectively. In this breakdown, lighting accounts for as much as 15%, 36%, 40.5% and 69.5% in Rural, Urban, Specialist and Teaching hospitals, respectively. Also, Figure 2 shows the energy performance according to functions by type of hospital. As shown in Figure 2, next to lighting functions in energy usage, are equipment operations in all the hospital categories. The identified trends in Figure 2 show how Nigerian hospitals prioritize their energy utilization. However, this may not represent the order of significance to hospital functions. The observed trend rather has revealed lighting function as an area for energy optimization in the hospitals, although further analysis is outside the scope of this study.

Based on survey data and results, a productive energy indicator value of 3.346 kWh/bed space/day; 2.367 kWh/bed space/day, 4.548 kWh/bed space/day and 19.443 kWh/bed space/day are consumed, respectively, by the typical Rural, Urban, Specialist and Teaching hospitals studied.

Table 1 Estimation of daily energy consumption per equipment for each hospital category

Equipment function	Qty of equipment (A)				rating watts (B)	On-time hours /day (C)	$f=(\frac{a\times b\times c}{1000})$ kWh/day (D)			
	R	U	S	T			R	U	S	T
Vaccine refrigerator	2	4	5	25	60	6	0.72	1.44	1.8	9.4
Centrifuge	2	4	5	6	575	6	6.9	13.4	17.25	20.7
Microscope	2	6	6	6	15	6	0.18	.54	.54	.54
Incubator	-	3	1	3	400	6	-	7.2	2.4	7.2
Autoclave	1	2	2	3	1,564	6	9.4	18.77	18.77	28.15
Oxygen concentrator	1	2	1	3	300	6	1.8	3.6	1.8	9.0
Computer desktop	1	10	15	34	150	10	1.5	15	13.5	51.0
Printer	1	10	15	34	65	10	0.65	6.5	13.5	22.1
Monitor	1	10	15	34	65	10	0.65	6.5	13.5	22.1
TV (color)	1	8	15	20	60	10	0.6	4.8	9.0	12.0
Ceiling fan	13	20	120	450	40	6	5.2	4.8	28.8	180.0
Kerosene stove	2	-	-	-	9500	1	19.0	-	-	-
Standing fan	3	15	80	160	40	6	0.72	3.6	19.2	64.0
Compact lamp	25	135	250	1250	15	8	3.0	12.15	22.5	109.5
Incandescent	16	313	450	3450	60	8	7.68	112.68	162.0	1242.0
Borehole-sumo pump	1	4	2	3	2 Hp	6	8.95	17.90	8.95	13.43
E.C. G	-	-	2	3	1440	1.5	-	-	4.32	6.48
Air conditioning	-	6	10	37	40	6	-	1.44	2.4	8.88
spectrometer	-	1	-	3	575	6	-	3.45	-	10.35
Tissue culture	-	-	-	3	475	6	-	-	-	8.55
Dialysis machine	-	-	-	3	575	6	-	-	-	10.35
Ultra sound	-	2	1	6	1440	6	-	17.3	8.64	51.8
X-Ray machine	-	2	3	3	3000	6	-	36.0	54	54.0
Oxygen	1	2	3	3	300	10	1.8	3.6	5.4	5.4
Washing machine	-	-	-	3	100	6	-	-	-	1.8
Hermatology mixer	-	4	4	3	28	6	-	.67	.67	.54
Gross total of energy used							66.93	343.23	454.87	1944.4

These provide reliable information for estimating the energy cost component in the billing of a patient. For example, using the Power Holding Company of Nigeria (PHCN) tariff rate of ₦ 12.89 ($ 0.083) per 1 kWh, the average cost of energy per bed space in the representative hospitals are ₦ 43.12, ₦ 30. 51, ₦ 58.62 and ₦ 250.62, respectively. Their corresponding building energy index (BEI), which indicates energy utilization per unit area, is calculated as the quotient of gross energy consumed over the built-up area. The respective BEI values for the hospitals are as follows: Rural at 0.13 kWh/m^2, Urban at 0.077 kWh/m^2, Specialist at 0.088 kWh/m^2 and Teaching hospital at 0.277 kWh/m^2. The BEI indicator will be useful in managing energy usage with daily patient turnover per bed space. A low BEI implies that a building has low rates of sick building syndrome symptoms.

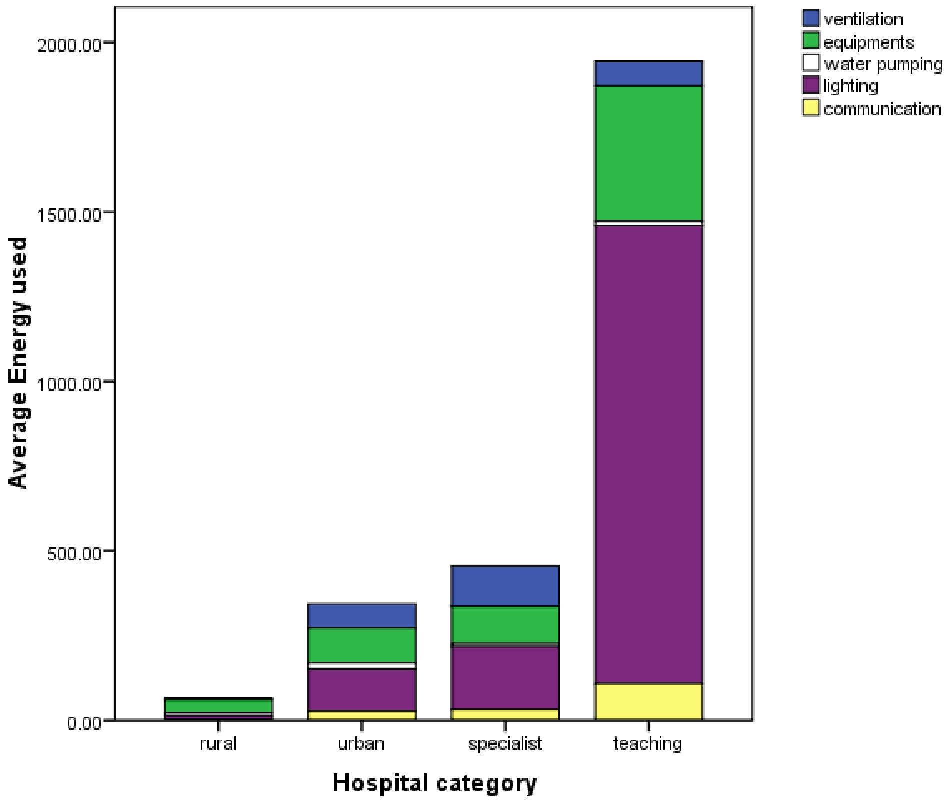

Figure 2 Component bar chart of energy usage in hospital according to function and type of hospital

Relating the BEI values to different building types and their uses, the BEIs for specialist and teaching hospitals performance are low, compared with the standard, 50-80 W/m^2 in the literature.

3.1. Self Generation of Electricity by Generator

In this survey, all the hospitals were observed to have installed standby generators. An average hospital considered in this study consumes 11 litres, 20 litres, and 40 litres of gasoline per day according to usage schedule of the following categories of Rural, Urban and Specialist hospitals, respectively. The Teaching hospital uses 100 litres of diesel per day. Using an average commercial gasoline price of ₦ 100 per litre and ₦ 120 per litre for diesel, these hospitals spend ₦ 1100, ₦ 2000 and ₦ 4000 on gasoline and ₦ 12,000 on diesel per day. This cost of electrical generation by generators is expensive compared to metered grid electricity, which is between ₦ 40001- ₦ 8000, ₦ 8001- ₦ 12000, ₦ 12001- ₦ 30000 and ₦ 50000 per month for Rural, Urban, Specialist and Teaching hospitals, respectively. This cost of energy services is shifted to patients and it has a rebound effect of limiting the ability of individuals to access healthcare, particularly in rural areas. The use of generators for running hospital services represents a potential deprivation and it is a proxy indicator of energy poverty in Nigeria.

As observed in this study, the crucial services of lighting and mechanical power for running equipment depend on liquid petroleum products. Although auto-generation presents a second-best solution, its use is restricted to emergency usage. Emergency usage is insensitive to microclimatic changes that act to the detriment of in-patients.

3.2. Lighting Systems in Nigerian Hospitals

Lighting is a key energy function in hospitals and critical to night and theater activities. Calculation of the Lighting Energy Numeric Indicator (LENI) follows in Equation 5.

$$LENI = \frac{L_{L,t}}{A} \tag{5}$$

where $L_{l,t}$ is the total energy for illumination function per hospital, and A is the area of hospital occupied patients.

Lighting energy numeric indicators for the categories of hospital investigated in this study are as follows: 0.02 kWh/m^2, 0.03 kWh/m^2, 0.04 kWh/m^2, and 0.19 kWh/m^2 for Rural, Urban, Specialist and Teaching hospitals, respectively. It was observed from the survey that a large proportion of lighting energy expenditure by hospitals is due to continued preference of incandescent lamps over eco-friendly compact flourescent or light emitting diode (LED). The hospitals consume much more energy for the same duration of time in running incandescent lamps compared to compact fluorescent lamps. For an efficient lighting system, compact fluorescent bulbs should be used in preference to tungsten bulbs in patient rooms. Also, the use of capacity-based electricity generation methods, such as the photovoltaic (PV) system, is preferable to a petrol or diesel based captive system. PV application presents a great opportunity for energy savings in hospitals.

Despite the environmental implications of the use of fossil fuels and the use of PV, particularly in Nigerian hospitals, is still limited. Therefore, design of a PV system is carried out and applied in this section of the paper as a sustainable solution to hospital energy performance improvement.

A benefit of using the PV system to power hospital services lies in sizing it according to the user's projected needs, goals and budget. It uses climatic data specific to an assigned location as planning support base and the uniqueness of the base makes it ideal for off-grid applications.

Table 2 Monthly solar energy and surface meteorology availability in Owerri, Nigeria

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m²/day	5.78	5.87	5.43	5.09	4.74	4.36	3.89	3.79	3.96	4.27	4.89	5.41
Clearness, 0-1	0.61	0.59	0.52	0.49	0.47	0.44	0.39	0.37	0.39	0.43	0.51	0.59
Temperature, °C	25.43	25.86	25.81	25.77	25.67	24.75	24.04	23.94	24.15	24.44	24.68	24.73
Wind speed, m/s	2.75	2.97	2.71	2.39	2.23	2.81	3.21	3.37	2.96	2.35	2.25	2.40
Precipitation, m m	22	47	122	180	241	290	346	286	362	261	76	18
Wet days, d	2.0	3.8	7.8	10.9	14.3	16.6	19.2	19.1	20.4	15.3	5.2	2.0

Source: These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center (Perez-Lombard et al., 2008)

With this potential flexibility, PV energy can be described as a capacity-based energy source, although a fundamental step in maximising the advantages is to get its sizing correct. For this purpose, we have demonstrated its use in providing power to Theophilus Hospital, a rural health facility located in Mbaise, with loads as shown in Appendix A, column D(R). Realization of this objective depends on solar insolation availability and to proceed the insolation data of Owerri near Mbaise, as shown in Table 2, was used.

The PV application in the hospital was based on order of priority as follows: water pumping; equipment; lighting and communication. Water pumping is the first in preference because the closest natural stream is 20 kilometers away from the hospital location. The villagers depend on rain and commercial water supplies for their daily water requirements. The public pipeborne supply that was constructed in 1964 is in a state of disuse. Due to its lack of proximity to a water point, the hospital relies on a borehole supply system. The provision of water by borehole to patients is a positive step, but having reliable energy for cost-effective water supply is a greater necessity. In a study by WHO and SEARO, (2005) 40 litres was found to be the minimum daily water requirement for an in-patient. Based on this requirement and to cost-effectively meet up water needs of Theophilus Hospital in Mbaise with a 20-person, in-patient capacity, a summary of the design criteria for the PV solar water pumping system is shown in Table 3.

Table 3 A summary of the design criteria for the solar water pumping system

Parameter	Value	Units
Water requirements	1000	Liters/day
Storage for three days	3000	Liters
Average daily insolation	4.79	kWh/m^2/day
Design water pump flow rate	3.06	Liters/min
Total dynamic head	50	Meters
Installed submissive pump rating:		
Water horsepower (WHP)	1.49	kilowatt(kW)
Operating voltage	60	Volts (V)
Efficiency	90	%
Brake horsepower (BHP)	1.65	kW
PV solar panel rating:		
Peak power output	180	watt (W)
Peak voltage	24	Volts (V)
Peak current	7.5	Amps
Panel description:		
Total numbers of panels	6	
Writing combination	3 series and 3 parallel	
Inverter rating	2	kW
Efficiency	90	%

4. CONCLUSION

This paper presents energy performance indicators and a summary of how Nigerian hospitals prioritize their power supply. Investigating energy performance is important in order to identify savings potential based on past consumption. The research used a systematic field survey followed by in-depth statistical analysis. The field survey investigated four categories of hospital, namely Rural, Urban, Specialist and Teaching hospitals; it took into account medical equipment and ventilation facilities in addition to patient population, lighting points and manpower requirements. Then, questionnaires were designed, randomly administered on and their responses generated in conversation with workers at 70 hospitals in Nigeria. It estimated the total energy requirements used in patient rooms and calculated metrics for assessing energy performance in rural hospital buildings.

Results of the analysis show that an average hospital in Nigeria, depending on its status, uses energy as follows: Rural - 66.936 kWh/day; Urban - 343.23 kWh/day; Specialist - 454.872 kWh/day, and Teaching - 1944.394 kWh/day. Statistic energy values of 3.346 kWh/bed space/ day; 2.367 kWh/bed space/day; 4.548 kWh/bed space/day and 19.443 kWh/bed space/ day are consumed, respectively, by typical Rural, Urban, Specialist and Teaching hospitals. The respective BEI values for the hospitals are as follows: Rural - 0.13 kWh/m^2; Urban - 0.077 kWh/m^2; Specialist - 0.088 kWh/m^2 and Teaching - 0.277 kWh/m^2. The BEI can be effective in measuring performance with patient turnover. The lighting energy performance values can be improved, if incandescent lamps are completely replaced with eco-friendly compact or LED bulbs. Also, stand-alone auto-generation is predominantly used in all the hospitals, when grid utility supply is unavailable or unreliable. Although, auto-generation presents attractive solutions, it is restricted to emergency usage.

Some challenges affected smooth conduct of the study. A major challenge the authors faced was unavailability of data as bookkeeping of energy consumption data is fairly difficult to obtain in hospitals. The implication of the lack of bookkeeping of energy information is the inability to obtain several years' data. The paper has identified lighting function as a possible area for energy optimization in Nigerian hospitals. Much of the hospital energy consumption could be reduced by a significant amount by the implementation of cost-efficient measures, such as the PV system. Further study on cost allocation systems for energy supplies to the hospital is being recommended.

5. ACKNOWLEDGEMENT

The authors wish to express their gratitude to hospitals that provided data for this work.

6. REFERENCES

Al-Karaghouli, A., Kazmerski, L.L., 2010. Optimization and Life-cycle Cost of Health Clinic PV System for a Rural Area in Southern Iraq using HOMER Software. *Solar Energy*, Volume 84, pp. 710–714

Bosch, J.P., Glaser, E., 2012. *Powering Health: Electrification Options for Rural Health Centers*, United States Agency for International Development, USAID. Available at: http://www.pdf.usaid.gov/pdf_docs/PNADJ557.pdf, Accessed on March 2, 2013

CEN/TC 169 N 0618, 2013. *PrEN 15193: Energy Performance of Buildings – Energy Requirements for Lighting*, Available at: http://www.iar.unicamp.br/../en_15193-1_energy_requirements, Accessed on April 8, 2013

Chen, Qingyan, 2009. Ventilation Performance Prediction for Buildings: A Method Overview and Recent Application. *Building and Environment*, Volume 44(4), pp. 848–859

Degelman, L.O., Soebarto, V.I., 2013. *Vital Signs: Whole Building Energy Performance-simulation*. Available at: http://www.arch.ced.berkeley.edu/vitalsigns/res/downloads, Accessed on April 8, 2013

E-Source Customer Direct, 2010. *Managing Energy Costs in Hospitals*. US Energy Information Administration, pp. 1–4

Gordo, E., 2011. Energy Efficiency in a Hospital Building Case Study: Hospitnis da Uviversidade de Coimbral, Portugal. Energetics IYCE 2011. In: *the Proceedings of the 2011 3rd International Youth Conference on Energetics*, Available at: http://www.ieeexplore.ieee.org, Accessed on February 21, 2013

Hu, S.C., Chen, J.D., Chuah, Y.K., 2004. Energy Cost and Consumption in a Large Acute Hospital. *International Journal on Architectural Science*, Volume 5(1), pp. 11–19

Jimenez, A.C., Olson, K., 1998. *Renewable Energy for Rural Health Clinics*. National Renewable Energy Laboratory, NREL Colorado, USA, Available at: http://www.nrel.gov/docs/legosti/fy98/25233.pdf , Accessed on March 5, 2013

Life04 EMV, 2013. *Guideline for Energy Efficiency Measures in Hospitals*. Life-Environment EMAS and Information Technology in Hospitals, Life04 EMV/GR/000114, Available at: http://ec.europa.eu/environment/life/project, Accessed on February 27, 2013

NASA Langley Research Center, 2002. *Owerri, Nigeria-Sunrise, Sunset, Dawn and Dusk Times*, Available at: http://www.gaisma.com/eu/location/owerri.html, Accessed on September 2014

Nwanya, S.C., Ekechukwu, O.V., 2013. The Energy Performance of Hospital Buildings in Nigeria. In: *the Proceedings of the Conference of Young Scientist in Energy (CYSENI)*, May 29-31, Kaunas, Lithuania, Volume V, pp. 302–309

Perez-Lombard, L., Ortiz, J., Pout, C., 2008. A Review of Buildings Energy Consumption Information. *Energy and Buildings*, Volume 40, pp. 394–398

Pinzone, M., Lettieri, E., Masella, C., 2012. Sustainability in Healthcare: Combining Organizational and Architectural Levers. *International Journal Engineering Business Management*, Volume 4(38), pp. 1–9

Seppanen, O., 2008. Scientific Basis for Design of Ventilation for Health, Productivity and Good Energy Efficiency. Available at: http://www.buildup.eu/system/.../Ventilation_IndoorAir08_Seppanen_2008.pd, Accessed on June 3, 2013

Singer, B.C., Mathew, P., Greenberg, S., Tschudi, W., Sartor, D., 2009. *Hospital Energy Benchmarking Guidance-version 1.0*. Ernest Orlando Lawerence Berkeley National Laboratory, California, pp 1–52

Stankovic, S., Campbell, N., Makimovic, O., Cvjetkovic, T., 2009. Evaluation of energy Efficiency Measures Applied in Public Buildings (Schools and Hospitals) in Serbia. *Spatium Inter. Review*, No. 20, pp. 1–8

WHO and SEARO, 2005. Minimum Water Quantity Needed for Domestic Uses. Available at: http://www.ec.europa.eu/echo/files/evaluation/watsan2005/annexfile/who/who5, Accessed on March 15, 2013

World Health Organization, WHO, 2013. Solar Energy and Rural Health Care. WHO fact sheet N132, Geneva, Switzerland, 1996, Available at: http://www.who.int/inf-fs/fact132.html, Accessed on 28 February 28, 2013

Yildiz, J., 2011. Identification of the Building Parameters that Influence Heating and Cooling Energy Loads for Apartment Buildings in Hot-humid Climates. *Energy*, Volume 36, pp. 4287– 4296