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Determination of Basic Principles For Achieving Sustainable Energy-Efficient Hostel Buildings In Federal Universities In South-East Nigeria

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ABSTRACT

Carbon dioxide (CO_2) emissions, especially those resulting from the burning of fossil fuel for energy, play a great role in global greenhouse emissions. These emissions currently affect man and his environment. One of the key consequences of greenhouse gas emissions is excessive heat generation and climatic change effects. These effects extend to man's health, and his survival. Improving energy efficiency in existing hostel buildings can help to reduce greenhouse gas emissions and ensure sustainability. This research aims to determine the basic principles for achieving sustainable energy efficiency in hostel buildings within Federal Universities in South-East Nigeria. This study, which is essentially survey-based and quantitative data, was derived from responses generated by questionnaire survey and fieldwork. A total of 376 questionnaires were administered to students of Nnamdi Azikiwe University, Awka Anambra State, Michael Okpara University of Agriculture, Umudike, Abia State and Federal University Ndufo-Alike, Ebonyi State. The students had spent more than two years living in the hostels. The tools used for data analysis were simple tables, Likert scale, mean score and student T-test. All hypotheses were tested at 5% level of significance. The findings of this revealed that planting of trees around the hostel buildings to cool the environment and sun shedding with the mean score of 4.9 were rated as the most important basic principles for achieving energy efficiency in hostel buildings in the study area. The study recommends that trees should be planted around hostel structures for shade, as this ensures cooler ambient temperatures and stabilizes the thermal comfort of buildings.

Keywords: Buildings; energy usage; energy efficiency; sustainable energy.

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INTRODUCTION

Nwofe (2014) adduced that there is unsustainable use of energy in most Nigerian university buildings , emphasizing the urgent need for measures to improve energy use within these institutions. The use of energy efficient systems has increased in recent years due to the growing demand in energy used for heating and cooling buildings. Without energy, buildings cannot be operated or inhabited. Recently, some technological improvements have been made in plant insulation, lighting, and control, as these are significant features that help towards achieving an energy efficient building. The technological improvements involve some technical processes for which old equipment can be replaced with an energy efficient system (Herring, 2006). Energy efficient buildings are those which consume less energy while maintaining the comfort conditions for their occupants compared to standard buildings.

Energy use in buildings, according to Fasakin (2009), accounts for about 75 % of a country's total energy consumption. This percentage depends greatly on the degree of electrification, the level of urbanization, the amount of building area, the prevailing climate, as well as national and local policies to promote energy efficiency. Space heating, cooling and lighting, which together account for a majority of building energy use, depend not only on the energy efficiency of the temperature control and lighting systems, but also on the energy efficiency of the buildings in which they operate.

Building, designs in terms of orientation and materials have a significant effect on the energy consumed for a selected set of end users.

Wong and Li (2007) highlighted that the energy efficiency of a building is the extent to which the energy consumption per square metre of floor area of the building measures up to the established energy consumption benchmarks for that particular type of building under defined climatic conditions. These benchmarks are applied mainly to heating, cooling, air conditioning, ventilation, lighting, fans, pumps and office or other electrical equipment, and electricity consumption for external lighting.

Lately, European Construction Technology Platform-ECTP (2013) asserted that buildings constitute 40% of total European Union's energy consumption and generate 36% of greenhouse gases in Europe. The ECTP's energy usage statistics emphasizes that energy efficiency in buildings to be taken seriously by the governments in both developed and developing countries. Therefore, the Nigerian Energy Support Programme (NESP, 2013) posited that concerted efforts are constantly made by governments to ensure that their countries continually tend towards buildings that use less energy while still sustaining appreciable levels of functionality for their operations and comfort for their occupants. In developing countries like Nigeria, with a growing population of over 160 million people currently generating total energy below 5,000 MW, the total energy usages leave many Nigerians, especially stakeholders in the building industry, much to desire.

Consequently, it is glaring that universities' hostel buildings in South-Eastern Nigeria are most poorly designed in terms of utilizing passive design strategies. For instance, some hostel buildings lack enough illumination to be functional within the day and end up using artificial means for illumination. Also hostel buildings become too hot due to excess solar heat gain and require alternative cooling methods, such as Home Ventilation and Air Conditioning (HVAC) to mitigate the problems and ensure sustainable development.

In a recent survey conducted by Obiegbu, et. al (2017), it is revealed that about 89% of universities in Nigeria still use energy efficient sources to heat up their buildings. About 63% of the surveyed institutions are universities from South-east Nigeria. Therefore, in a bid to secure a lasting panacea to this statistical record, the researchers delved into studying the extent of energy efficient uses in South-East Nigerian universities, and to possibly find the best way to resolve the matter in order to encourage sustainability in energy usages in the sampled institutions.

Basic Principles and Strategies for Achieving Energy Efficient Hostel Buildings

The energy efficiency principle focuses on reducing energy operations, such as cooling, heating, lighting and other appliances without affecting the occupants comfort and health. Improvement of energy efficiency does not only have environmental benefits, but also economic benefits, especially operational cost saving (Ruparathna et al.,2016). This includes lowering heat by adjusting thermostats, and setting standards for appliance' consumption and capacity. It basically points towards understanding consumers' behaviour, regulation and lifestyle change.

Kornelis et. al (2007) submitted that an integrated design approach is a prerequisite for achieving energy efficient buildings. This approach involves collaboration among architectural elements and engineering systems towards realizing a sustainable energy efficient system. The following principles guarantee energy efficiency.

Reduction of heating, cooling and lighting loads in hostel buildings

In order to reduce heating and cooling loads, one of the simple strategies that could be adopted is to isolate the hostel buildings from the environment by using high levels of insulation, optimizing the glazing area and minimizing the infiltration of outside air. This approach is most appropriate for cold, overcast climates. Another more effective strategy is the usage of building envelope as a filter, besides selectively accepting or rejecting solar radiation and outside air. This depends on the need for heating, cooling, ventilation and lighting at a specific period, as well as using the heat capacity of the hostel building structures to shift thermal loads on a time scale of hours to days. The essence of this strategy is to use the building as filter to selectively accept or reject solar radiation and outside air, depending on the need for heating, ventilation and air conditioning (FMPWH, 2016).

Utilizing active solar energy and other environmental heat sources and sinks

Active solar energy systems can provide electricity generation, hot water and space conditioning. The ground, ground water, aquifers and open bodies of water, and less air, can be used selectively as heat sources or sinks, either directly or by using heat pumps. Space cooling methods that dissipate heat directly to natural heat sinks without the use of refrigeration cycles (evaporative cooling, radiative cooling to the night sky, earth-pipe cooling) can be used (Obiegbu et al., 2017).

Increasing efficiency of appliances, heating and cooling equipment and ventilation in hostels

The efficiency of equipment in hostel buildings continues to increase in most industrialized and many developing countries, as it has over the past quarter-century. Increasing the efficiency and where possible reducing the number and size of appliances, lighting and other equipment within conditioned spaces reduces energy consumption directly. It also reduces cooling loads, but increases heating loads, although usually by lesser amounts and possibly for different fuel types.

Implementing, commissioning and improving operations and maintenance

The real performance of a building is dependent on two critical and fundamental ingredients: a) quality of design, and b) superiority of construction. Building commissioning involves a broad spectrum of Quality Control and Assurance (QC/QA) practices that include, but not limited to: design review, functional testing of energy consuming systems and components, proficient maintenance culture, operational readiness and good documentation (GDocP), continuous performance monitoring, automated diagnostics and improved operator training. These are complementary approaches for improving the operation of commercial buildings in particular.

Changing behaviour

The energy use of a building depends to a notable extent on the behaviour and decisions of its users. Literature suggests that when building managers know that energy consumption is monitored, electricity consumption falls. The behaviour of residents of university hostel buildings also has a substantial impact on energy use, especially when lighting, heating and ventilation are controlled manually (Ueno et al., 2006).

Utilizing system approaches to hostel building design

Evaluation of the opportunities to reduce energy use in buildings can be done at the level of individual energy-using devices or at the level of building 'systems' (including building energy management systems and human behaviour). Energy-efficient strategies focused on individual energy-using devices or design features are often limited to increased improvements. Examining buildings as an entire system can lead to entirely different design solutions. This can result in new buildings that use much less energy but are no more expensive than conventional buildings. The systems approach in turn requires an Integrated Design Process (IDP), in which the building performance is optimized through an iterative process that involves all members of the design team from the beginning (ECN, 2013). The basic steps in realizing IDP for a commercial building include:
(i) Selecting a high-performance envelope and properly sized highly efficient equipment,
(ii) Incorporating a building energy management system that optimises equipment operation and human behaviour
(iii) Fully commissioning and maintaining the equipment.
These key steps typically reduce energy savings by 35-50% in new commercial buildings. More advanced or less conventional approaches may result in increased energy savings, by 50-80% (Charalamides, 2009).

Considering building form, orientation and related attributes

At early design stages, key decisions – usually made by the architect – can greatly influence subsequent opportunities to reduce building energy use. These include building form, orientation, self-shading, height-to-floor-area ratio and decisions affecting the opportunities for and effectiveness of passive ventilation and cooling. Many elements of traditional building designs in both developed and developing countries have been effective in reducing heating and cooling loads. Urban design, including the clustering of buildings and mixing of different building types within a given area greatly affect opportunities for and cost of district heating and cooling systems (NBC, 2019). The overarching objective is to employ strategies that improve passive ventilation and cooling.

Strategies for Achieving Energy Efficient in Hostel Buildings

Community Research and Development Centre asserts that obtaining energy efficiency in hostel buildings is an important aspect of achieving sustainable development (CREDC, 2009). Efficient energy usage in hostel buildings directly reduces a tertiary institution's overall financial burden. Monies realised or recovered may be ploughed into the research and development of alternative energy sources.
The outcome of a Federal Energy Management Program conducted in 2010 that primarily focused on low energy building design guidelines indicated a great variability in distinctive energy-saving techniques, strategies, and mechanisms per project, depending on building and space type (insert citation). Choice and conformation are influenced by:
i. Climate
ii. Internal heat gains from occupants and their activities, lights, and electrical equipment
iii. Building size and massing
iv. Illumination (lighting) requirements
v. Hours of operation
vi. Cost of electricity and other energy sources
Therefore, the basic energy-saving techniques below should be used to reduce building energy use.

- Sitting and organizing the building configuration and massing to reduce loads.
- Reducing cooling loads by eliminating undesirable solar heat gain.
- Reducing heating loads by using desirable solar heat gain.
- Using natural light as a substitute for (or complement to) electrical lighting.
- Using natural ventilation whenever possible.
- Using more efficient heating and cooling equipment to

Table 1: Gender of the respondents.

Items	Number	Percentage %
Male	160	45.5
Female	192	54.5
Total	352	100

Source: Survey Questionnaire of the Study, (2023).

satisfy reduced loads.

• Using computerized building control systems.

A manual by Energy Commission of Nigeria on sustainable design and energy efficiency measures arranged the strategies for achieving energy efficiency into three groups (Energy Commission of Nigeria, 2013):
Strategies that reduce the whole energy load within the hostel building
Strategies that improve the efficiency of the systems
Strategies that involve on-site generation of electricity via the use of renewable resources.

These energy-efficient strategies should help to improve the whole sustainable performance of hostel buildings, especially in improved access to daylight and views, indoor air quality, occupant comfort etc.

The Nigeria Energy Support Programme(NESP, 2013) further mentioned that the cost-effectiveness of an energy efficiency measures differs by region and climate. Furthermore, there is no single amalgamation of measures that will offer the expected ideal energy efficiency. Therefore, project teams should continuously evaluate completely the conceivable and suitable actions to ensure that the most cost-effective solutions are acquired.

METHODOLOGY

This study involves fieldwork (survey), as well as the use of research questions to elicit relevant information from the targeted respondents, hence the use of survey research design. Questionnaires were administered to a sample size of 376 students of Nnamdi Azikiwe University, Awka; Michael Okpara University of Agriculture, Umudike Umuahia, and Federal University Ndufo-Alike, Abakalikki, using Taro Yamane sample size determination method. The survey population was students who had spent more than two years living in the university hostels. The institutions were randomly selected through a simple random sampling technique. The selected institutions represented universities in the South-eastern states of Nigeria. Furthermore, survey questionnaire was designed to obtain representative views of the respondents on the basic principles for achieving energy efficient hostel buildings in South - East, Nigeria within a set of attributes rated.

A likert scale (rating: 1-5) was used to measure variability of the respondents' opinions about relative worthiness of attributes in subsets. Questions were structured to explore the respondents' opinion of energy efficient hostel buildings on campus; responses further provided insight on the students' wellbeing in the university environment.

Out of 376 questionnaires, 352 (94%) were duly completed and returned. Data obtained from the questionnaires were analysed using simple tables, Likert scale, mean score and student T-test. All hypotheses were tested at 5% level of significance. The results, as derived from Tables 1-6, were presented as findings in section 4.0. From the results of the study, conclusions were drawn, having analysed the basic principles for achieving energy efficient hostel buildings in the study areas.

RESULTS AND DISCUSSIONS

Socio-demographic Characteristics of the Respondents

Table 1 shows that 54.5 percent (54.5%) of the respondents were females and 45.5 percent (45.5%) were males. The variation in gender percentage distribution, fundamentally, during the administration of research questionnaire, was prominent, as female students received higher copies of the research questionnaire than their male counterparts. This is due to the existing demographic data obtained from the sampled institutions which showed women-dominant sampled population. Therefore, based on the existing students' demographic data, it does appear that there was an over-representation of female respondents in the survey, which could lead to bias. However, the bias was eliminated as the gender demography is almost the same across all the institutions in the South-east Nigeria. This assertion was corroborated by the submissions of the National Building Code (2019), under housing and demography.

Table 2 shows that 84.6 percent (84.6%) of the respondents were between ages 16-40 who were undergraduate, 11 .4% and 4.0% were between the ages of 41-50 and 51 years and above respectively who were Postgraduate, Part-Time and Regular students. Accordingly, more than 84.6 % of the data were obtained from people of between 16 -40 years of age. Hence, it showed that most of the data for this study were obtained

Table 2: Age Bracket of Respondents.

Age	Number	Percentage %
16 – 40	298	84.6
41 – 50	40	11.4
51 and above	14	4.0
Total	352	100

Source: Survey Questionnaire of the Study, (2023).

Table 3: Programme of Study of the Respondents.

Items	Number	Percentage %
Undergraduate	238	67.6
Postgraduate	43	12.2
Parttime	60	17.1
Certificate	11	3.1
Total	352	100

Source: Survey Questionnaire of the Study, (2023).

Table 4: Mean Score of the Responses on Basic Principles for Achieving Energy Efficient Hostel Building (n=352).

	Items	Mean Score
1	Planting of trees around the building to assist in cooling of the environment and sun shedding	4.9
2	Installation of solar energy devices to supplement other power sources	4.6
3	Consider building form, orientation and related attributes	4.5
4	Re-commission all energy and water systems to verify if they are functioning at optimum performance; then renovate energy and water systems to minimize consumption	4.4
5	Increase the efficiency of appliances, heating and cooling equipment and ventilation in the hostel.	4.3
6	Reducing heating loads by using desirable solar heat gain	4.3
7	Insulating the hostel such as installing or replacing high voltage bulbs with fluorescent lights	4.3
8	Installation of solar shading devices for windows and doors, as well as those that generate electricity by photovoltaic (PV) devices	4.3
9	Mounting of solar energy devices	4.3
10	Assess hostel patterns, and then apply daylight heating, ventilation and air conditioning (HVAC) and lighting sensors where suitable.	4.2
11	Reduce heating, cooling and lighting loads.	4.2
12	Utilize active solar energy and other environmental heat sources and sinks	4.2
13	Putting off electrical appliances when not in used to reduce cost.	4.2
14	Change behaviour	4.2
15	Utilize system approaches to building design.	4.2
16	Using more efficient heating and cooling equipment to reduced loads	4.2
17	Installation of a cool or green roof surface that shade against solar radiation	4.1
	Total Mean Score	81.7

Source: Survey Questionnaire of the Study, (2023).

from field survey involving undergraduate students of the federal universities which was apt for the study. The implication of analyzing the students' demographic data is to assist in determining the extent of possible heat emissions from the students living in the hostels of the federal universities and to help in determining the impacts of an increased rooms thermal temperatures as a result of energy efficient absorbents in the sample population areas.

Table 3 shows that 67.6% of the respondents were undergraduate students, 12.2% were postgraduate students, 17.1 were portals. This shows that majority of the respondents were undergraduate students and there is more energy efficiency in hostels occupied by undergraduate students compared to hostels occupied by post-graduate students and portals. This by extension means that concerted alternative energy sources like the use of energy saving bulbs and solar converters is needed more in undergraduate hostels than other hostels. This will ameliorate the possibility of spread of heat wave in these hostels, thereby impacting positively the structures and students alike.

Table 4 examines the basic principles for achieving sustainable energy efficient hostel buildings in the study

Table 5: T-Test on One-Sample Statistics on Mean Score of the Responses on Basic Principles for Achieving Energy Efficient Hostel Building.

	N	Mean	Std. Deviation	Std. Error Mean
Basic principle for achieving energy efficient hostel buildings	352	81.5938	16.45203	.87690

Source: Survey Questionnaire of the Study Extracted from SPSS, (2023).

Table 6: One-Sample t-test.

	Test Value = 0						
						95% Confidence Interval of the Difference	
	t-cal	t-tab	Df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Basic principle for achieving energy efficient hostel buildings	93.048	2.995	351	.000	81.59375	79.8691	83.3184

Source: Survey Questionnaire of the Study Extracted from SPSS (2023).

areas, considering their mean scores ranging from 4.9-4.1 (see Appendix 1).

Our investigations reveal that the respondents consider basic principles 1-4 the most profound in achieving energy efficiency in hostel buildings. Planting of trees around the buildings to assist in cooling of the environment and sun shedding, installation of solar energy devices to supplement other power sources, building form, orientation and related attributes, and the re-commissioning of all energy and water systems to verify if they are functioning at optimum performance alongside renovating energy and water systems to minimize consumption rank higher than principles 5-17 (4.9, 4.6. 4.5. 4.4 respectively).

Increasing the efficiency of appliances, heating and cooling equipment and ventilation in the hostel, reducing heating loads by using desirable solar heat gain, insulating the hostel such as installing or replacing high voltage bulbs with fluorescent lights, installation of solar shading devices for windows and doors, as well as those that generate electricity by photovoltaic (PV) devices, mounting of solar energy devices and assessing hostel patterns, applying daylight heating, ventilation and air conditioning (HVAC) and lighting sensors where suitable rank lower in terms of importance with a mean score values of 4.3 and 4.2 respectively. The installation of a cool or green roof surface, which provides shade against solar radiation has the lowest rank in terms of importance, with a mean score value of 4.1.

Now, comparing the results as obtained from Table 4, the student sample t-test was employed. The outcome is presented in Table 5.

Tables 4 and 5, with mean value of 81.5938 > 3.01, show the mean values from table 4.8, indicate that there are some basic principles and strategies of energy efficient hostel buildings**.**

Therefore, comparing the total mean from Table 4 with student t-test table carried out through SPSS, it was discovered that the total mean value is 81.7 while that of t-test table suggested 81.59, approximately 82. This suggests there is need for further test to establish the authenticity of the first result by subjecting these data into t-test analysis through SPSS.

Hypothesis: The null and alternate hypotheses are stated as below**:**

H_0: There is no significant difference between the basic principles for achieving sustainable energy efficient hostel buildings and sustainable building in the study area.

H_1: There is significant difference between the basic principles for achieving sustainable energy efficient hostel buildings and sustainable building in the study area.

Decision Rule

Reject the statement of hypothesis (the null hypothesis) if absolute value of t-calculated is greater than the t-tabulated.

Testing whether the basic principles for achieving energy-efficient hostel buildings are significantly different from sustainable buildings in the study area, the research employed one sample t-test using the data in Table 5.

The one-sample t-test result (Table 6) with a statistic value of 93.048 where t-cal. of 93.048 > t-tab 2.995 indicates that the basic principles for achieving energy efficient hostel buildings are significantly different from those of sustainable building in the study area. Hence, the null hypothesis is rejected.

CONCLUSION

In conclusion, the basic principles for achieving sustainable energy efficient hostel buildings such as;

planting of trees around the buildings to assist in cooling of the environment and sun shedding, installation of solar energy devices to supplement other power sources, considering building form, orientation and related attributes and re-commissioning all energy and water systems to verify if they are functioning at optimum performance, and renovating energy and water systems to minimize consumption are very important. Buildings that have tree planted around them could be shaded and record cooler ambient and internal temperatures than other buildings. Also, creating awareness and different campaigns can attract more attention to the issue of the increase of greenhouse gases. Therefore, hostel buildings should be designed to optimize energy in use, without compromising performance in terms of, air quality and comfort conditions.

Since the study has discovered that the basic principles for achieving energy efficient hostel buildings in the study area are significantly different from those of sustainable buildings, , university management should source their hostel building designs and construction from architects and building professionals who are responsive to the parameters of sustainable construction principles. This is to ensure that such architectural designs and construction processes conform to basic building environmental requirements. This might have a slight cost increase but will save the university much energy cost during the life cycle of the building.

University should develop a strategic approach to energy management including energy policy, identification of potential energy savings and investment opportunities, monitoring and evaluation of progress towards an energy efficient future. Most on-campus residents do not pay for energy bills, no feedback on energy usage, associated emission and cost incurred are unavailable, Consequently, smart metering should be installed in each hostel building and competition for energy savings be instituted with incentives to ensure more efficient use of energy in the university hostels.

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Appendix 1

Table 1: Mean Score of the responses on the sustainable approaches or practices for energy-efficient hostel buildings (n=352).

S/No	Item	(5) VI	(4) I	(3) UN	(2) NI	(1) NVI	Mean Score	Decision
	BEHAVIOURAL APPROACHES							
1	Single use of inefficient heating equipment	1145	260	57	28	25	4.3	Very Important
2	Non simultaneous Use of Multiple Appliances in the hostel	1010	348	42	60	19	4.2	Very Important
3	Non purchase of second-hand appliances	590	688	75	26	24	3.9	Important
4	Not leaving appliances on standby mode	750	456	45	54	46	3.8	Important
5	Putting appliance off when not in Use	260	864	51	129	24	3.8	Important
6	Switching off outdoor lighting during the day	535	660	45	26	52	3.7	Important
7	Putting off light when not in use	315	820	21	48	53	3.6	Important
	TECHNICAL APPROACHES	**5**	**4**	**3**	**2**	**1**		
8	Reducing energy used for heating water	695	728	81	46	31	4.5	Very important
9	Reducing electricity consumption of hostel equipment and appliances	680	836	0	14	0	4.3	Very Important
10	Reducing heating demand	605	600	117	60	12	3.9	Important
11	Reducing cooling demand	650	568	99	42	26	3.9	Important
12	Good housekeeping and people solutions	740	472	114	60	18	3.9	Important
13	Reducing the energy requirements for ventilation	650	464	171	76	11	3.8	Important
14	Reducing energy use for lighting	675	508	111	36	35	3.8	Important
	RENEWABLE ENERGY SOURCES	**5**	**4**	**3**	**2**	**1**		
15	Solar power	1395	184	81	0	0	4.7	Very Important
16	Photovoltaic	880	424	141	28	9	4.2	Very Important
17	Biomass	675	564	162	36	4	4.1	Very Important
18	Light-emitting diodes	640	584	63	96	25	4.0	Very important
19	Compact fluorescent lamps	820	452	21	51	11	3.8	Important
20	Geothermal	385	456	138	154	38	2.9	Unimportant

Appendix Contd.

21	Hydro sources	190	140	117	249	157	2.4	Not very Important
22	Incandescent light	40	132	78	252	149	1.8	Not very Important
	Mean						**83.34**	Important
	Total Mean						**3.8**	

Source: Field Survey, 2021