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Assessment of Energy Savings through Efficient Building Design. A case of The Federal University of Technology, Akure

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Abstract: *This study investigated the feasibility of saving the energy required in a building right from its design stage. The School of Engineering and Engineering Technology (SEET) building of the Federal University of Technology, Akure, Ondo State in Nigeria was used for the study. The indoor temperature and the illuminance of selected facilities within the building were measured and recorded, over a month; when the air conditioning and lighting systems were respectively switch off. Subsequently, the air conditioning (A/C) and the lighting requirements of the investigated facilities were estimated using existing formulae and design charts assembled for the purpose. It was ensured that the estimation took into consideration the ergonomics requirement of the investigated facilities to provide the needed comfort for their users in respect of the indoor temperature and the illuminance required for the teaching and research tasks being performed within the facilities. The recorded indoor temperature, illuminance as well as the estimated capacity of the air conditioning and lighting systems were compared to obtain information on how energy could be saved during building design. It was revealed, in very few of the facilities investigated, that for certain period of the day energy could be safe by switching off the air conditioning and lighting systems. This facilitates the computation of possible energy cost that could be saved and the recommendations on how building design could be explore to help in energy saving.*

Keywords- *Energy saving, thermal comfort, lighting, illuminance, cooling load*

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I. Introduction

A workplace is a location where someone works; such a place can range from a home office to a large office building, factory or learning environment. However, a well-designed, healthy workplace and/or learning environment with adequately managed energy programme would facilitate the control of energy use and subsequently helps to increase productivity and competitiveness. This can result in self-reputed productivity gains of up to 5%. Improving building's energy efficiency (and by implication ensuring optimum energy savings) will reduce energy cost, create a more pleasant work environment and extend the lifespan of the available equipment. In the last century the energy use increased a lot and the energy sources that were used were not the most proper ones. A lot of energy was taken out from hydrocarbons, whose combustion releases CO_2, a greenhouse effect gas [1, 2]. One of the measures that can be used to fight against this problem is to encourage the use of renewable and natural energy source and the other one is to save energy through facility design for lower energy requirement.

Energy is a property of objects which can be transferred to other objects or converted into different forms, but cannot be created or destroyed. The ability of a system to perform work is a common description. But, it is difficult to give a comprehensive definition of energy because of its many forms. In SI units, energy is measured in joules which is the energy transferred to an object by the mechanical work of moving it 1 meter against a force of 1 Newton. Buildings utilities such as lightings and air conditioners consume energy to provide comfort for building users.

The Nigerian Power sector has been bedeviled with series of problems. Critical to this is the consequence of human actions resulting in energy losses with its attendant challenges of energy cost and other economic implications.

In Nigeria, the Lagos State Government recently started encouraging residents of the state to imbibe energy saving culture through an initiative tagged "Conserve Energy, Save Money" spearheaded by the Lagos State Electricity Board (LSEB) under the Ministry of Energy and Mineral Resources. The initiative is designed to sensitize residents on the theme of energy saving by connecting with and influencing their behavior through do-it-yourself tips and exciting interaction with prominent personalities. To this effect residents were mobilized to participate on the topic of energy saving in an organized Google+ Hangout on YouTube. In addition to the hangout, LSEB hosted experience centers in malls around Lagos State where members of the public were encouraged to calculate their current household energy consumption. Also, solar lamps and energy-saving bulbs were given out at each experience center to get the people started on energy saving in their houses.

Buildings represent a big part of the energy consumed by a city. Therefore, they constitutes one of the main objects of study in the field of energy saving. Energy saving refers to reducing energy consumption through using less of an energy service. Energy savings differs from efficient energy use, which refers to using less energy for a constant service. For example, driving less is an example of energy saving. Driving the same amount with a higher mileage vehicle is an example of energy efficiency. Energy saving and efficiency are both energy reduction techniques. Even though energy saving reduces energy services, it can also result in increased environmental quality, national security, personal financial security and higher savings [3, 4].

Efficient energy saving involves reducing the amount of energy required to provide products and services. However, in energy conservation, energy is saved by reducing a service through cutting back on energy usage. Combining these two approaches, improvements in energy savings could generally be achieved by adopting a more efficient technology or production processes [1] or by application of commonly accepted methods to reduce energy losses. Reducing energy used reduces energy costs and may result in a financial cost saving to consumers if the energy savings offset any additional costs of implementing an energy efficient technology. Furthermore, improved energy efficiency in buildings, industrial processes and transportation could reduce the world's energy needs.

Residential and tertiary buildings have high energy requirements for heating, lighting and cooling/ventilation needs [5]. In order to reduce energy consumption in the buildings sector, public policies have been developed across the EU to encourage building owners to implement energy efficiency measures [6]. Considering the methodologies of energy savings from literature [3, 7], the main issues are: (1) analysis of building and utility data, including study of the installed equipment and analysis of energy bills (2) survey of the real operating conditions, (3) understanding of the building behavior of the interactions with weather, occupancy and operating schedules, (4) selection and the evaluation of energy conservation measures and (5) identification of inhabitants concerns and needs. Researchers have investigated energy usage in building through estimation of thermal and cooling loads and design of systems [8, 9, 10, 11, 12, 13, 14]. Most of the studies focused on optimizing the energy used by mechanical ventilation systems. However, when the object of study is an occupied building, then, reducing energy consumption while maintaining or improving human comfort, health and safety are of primary concern. Therefore, Appropriate studies could be conducted come up with ways of saving a lot of energy requirement of a building through adequate design of building for efficient energy saving and conservation [15]. One important area identified herein, that had not been explored, is whether building could be designed to use natural ventilation and lighting in place of the associated mechanical systems, at certain period of the day, thereby saving the energy needed for these purpose should mechanical systems be used. This is the subject matter of this study. Since, the various building making up the Federal University of Technology, Akure (FUTA) represents a very large part of the energy consumption of Akure and Benin Electricity Distribution Company (BEDC), FUTA is selected as the study location. This study will go a long way to help in suggesting appropriate approach to conserving electricity usage right from the building design phases.

II. Materials and Methods

Three Lecture rooms, two Laboratories, four (two-in-one) offices, twenty two normal offices, one conference room, one computer room, and one library were investigated. These facilities are located within the School of Engineering and Engineering Technology (SEET) building in FUTA. The average indoor temperature of the investigated facilities, without mechanical ventilation been used were measured and recorded over a month (twenty two working days) at an interval of 1 hour (between the usual time of arrival of occupants; 8:00 am and the departure time; 4:00pm). These values were compared with the Industrial Thermal Standard in respect of the task being performed by occupants of a facility. The occupant(s) should be convenient in an office, lecture room and/or Laboratory and any other facilities while performing his/her duties. The readings taken was used to determine the period of the day during which an occupant of a facility can work conveniently without mechanical ventilation but only exposed to natural ventilation from the environment. In a similar way, the average illuminance of each of the facilities over a month period was simultaneously measured without the lightings on. Subsequently, the standard ventilation and lightning requirements of the investigated facilities were assessed as discussed in section 2.1 and 2.2 respectively.

2.1 Ventilation System Requirement

Load Estimation using Cooling Load Temperature Difference (CLTD/CLF/SLF) technique, [16, 17, 18], was carried out on the investigated facilities. This was used to estimate ventilation needs of the facilities. The Indoor and Outdoor temperatures of each of the investigated facilities were measured using Thermometer while their relative humidity was measured using Hygrometer. The humidity ratios, W (grams moisture per kilogram dry air) of the inside and outside condition were obtained from the CIBSE Psychometric Chart. Load estimation was done and the mechanical ventilation load required for the facilities was determined. This was done so as to determine the power consumed when mechanical ventilation sources were used and the amount saved when not in use, taken the duration of use of these mechanical ventilation sources into consideration during the process.

2.1.1 Determination of Mechanical Ventilation Required

The total heat required to be removed from a given space of any of the facilities in order to bring it to the desired comfortable temperature and relative humidity by the air conditioning equipment according to ASHRAE Thermal Standard is known as cooling load or conditioned load. This load consists of external and internal loads. It is the sum of total sensible heat gain, total latent heat gain and factor of safety (10 % of the combined heat load) as used in Equation 1.

$$\mathrm{THL} = \mathrm{SHL} + \mathrm{LHL} + \mathrm{Factor\ of\ Safety} \qquad (1)$$

Where, THL is the total heat load, SHL is the total sensible heat load gained and LHL is the total latent heat load gained in respect of the facility under consideration.

The sensible heat load gained is a combination of all type of sensible heat gained at a conditioned space. These includes Sensible heat gain through walls, windows, doors, floors and ceilings, Sensible heat gain through glasses due to solar radiation, Sensible heat gain due to occupants, Sensible heat gain due to infiltration outside air, Sensible heat gain due to ventilation of outside air, Sensible heat gain due to lighting equipment and Sensible heat gain due to electrical appliance.

The latent heat load gained is also a summation of all type of latent heat gained at a conditioned space which includes the Latent heat gain due to infiltration of outside air, the Latent heat gain due to ventilations of outside air and the Latent heat gain from occupant.

The design of an air conditioning system depends on the type of structure in which the system is to be placed, the amount of space to be cooled, the number of occupants, and the nature of their activity [9]. Hence, Equations (2) to (13) extracted from ASHRAE [16], ASHRAE [17] and Khurmi and Gupta [19] were combined after measuring the appropriate parameters of each facility to estimate its cooling load and determine the capacity of air conditioning unit required. Contribution to cooling load from different sources/structures of the building could be estimated, in watt, as follows;

The Sensible Heat gain through building structure (Wall, Door, Ceiling/Roof, Window (Glass) and Floor)

$$\mathrm{Q_p} = \mathrm{U_p}\, \mathrm{A_p}\, (\mathrm{t_o} - \mathrm{t_i}) \qquad (2)$$

Where, $\mathrm{U_p}$ is the Thermal Coefficient/Transmittance for the building part x taken for roof, wall, door, windows, ceiling and floor as 2.31, 2.01, 2.61, 5.91, 14.71 and $2.31\mathrm{W/m^2K}$respectively [16, 17], $\mathrm{A_p}$ is the Area of the corresponding building part while $\mathrm{t_o}$ and $\mathrm{t_i}$ is the respective outdoor and indoor temperatures.

The Sensible Heat Gain through Glass Window Areas (Fenestration)

$$\mathrm{Q_{Fenestration}} = \mathrm{A.GLF} \qquad (3)$$

Where A is the area of the glass window, GLF is Glass Load Factor for glass in North, South, East and West direction are taken as 129, 189, 300 and 300 respectively [16].

The Heat Gain due to Infiltration of Outside Air (Sensible and Latent) could be estimated as follows

$$\mathrm{V_i} = \frac{\mathrm{L\times W\times H\times G}}{60} + \frac{\mathrm{D_o\ /hr \times F}}{60} \qquad (4)$$

$$\mathrm{OASH_i} = 20.43\ \mathrm{V_i}(\mathrm{t_o} - \mathrm{t_i}) \qquad (5)$$

$$\mathrm{OALH_i} = 50\ \mathrm{V_i}(\mathrm{W_o} - \mathrm{W_i}) \qquad (6)$$

Where, $\mathrm{OASH_i}$ and $\mathrm{OALH_i}$ is the Outside Air Sensible Heat and the Outside Air Latent Heat, in watt, due to infiltration respectively. Also, $\mathrm{V_i}$ is the total infiltration in m^3/s, L, W and H is the length, width and weight of the building structure respectively, G is the air change, $\mathrm{D_o}$is the door openings, hr is the period of heat gain in hour, F is the infiltration factor while $\mathrm{W_o}$ and $\mathrm{W_i}$ is the respective outdoor and indoor specific humidity.

The Heat Gain due to Ventilation of Outside Air (Sensible and Latent)

$OASH_v = 20.43\ V(t_o - t_i)$ (7)
$OALH_v = 50\ V(W_o - W_i)$ (8)

Where, $OASH_v$ and $OALH_v$ is the Outside Air Sensible Heat and the Outside Air Latent Heat, in watt, due to natural ventilation respectively. Also, V is the natural ventilation requirement recommended for people and it is usually taken as $0.75\text{m}^3/min$ per occupant [19].

The Heat Gain due to Occupants (Sensible and Latent) is as given in Equation (9) and (10) respectively.

Sensible heat gain due to Occupants = Sensible heat gain factor × Number of Occupants (9)
Latent heat gain due to Occupants = Latent heat gain factor × Number of Occupants (10)

The Sensible heat gain factor and Latent heat gain factor for occupant are taken as 75 and 55 W respectively [17].

The Sensible Heat Gain due to Lighting Equipment

$$Q_{\text{Light}} = \text{Total Wattage of Light} \times \text{Use factor} \times \text{Allowance factor} \tag{11}$$

Where the Use and Allowance Factor for Lighting Equipment are taken as 0.5 and 1.2 respectively [19].

The Sensible Heat Gain due to Appliance

$$Q_{\text{Appliace}} = \text{Appliance recommended heat gain} \times \text{Number of Appliance} \tag{12}$$

Recommended heat gain for computers, Laser printers and photocopiers are taken as 55, 320 and 1100 W respectively [17].

The Capacity of the Air Conditioning System, measured in Tonnes, is obtained from the total heat load as in Equation (13) after aggregating all sensible and latent loads discussed to obtain the total sensible and total latent load which add up to give the total heat load in Equation (1).
Hence, the cooling capacity of the air-conditioning system required in Tonnes of Refrigeration

$$CC_{ac} = \frac{\text{Total Heat Load}}{3500} \tag{13}$$

The effective cooling capacity, which properly should be expressed in kilowatt units and British thermal unit per hour (Btu/hr) is used to rate air conditioning units. The higher the compressor's Btu/hour, the higher the cooling capacity of the air conditioning system. However, a compressor of one horse power could support 3500 W of cooling, which is the equivalent of one ton of refrigeration. Also, it is known that one horse power is approximately equivalent to 750 W [20]. Hence the wattage of equipment rated in horsepower could be estimated.

2.2 The Lighting System Requirement

FUTA has a lighting system that is not too old, with Compact Fluorescent energy saving lamps. Improving the energy efficient in building using the energy saving lamps like Compact Fluorescent Lamps are suitable [21, 22, 23, 24]. All the facilities selected for this study were visited with a lux meter to measure their light intensity. The lux meter was used to measure the illuminance in the investigated facilities with the lightings off at different hours of the day. The recommended standard lux level, E, values for the investigated facilities, as extracted from FLD [25], Zumtobel [26] and IES [27], is 500 lux. Hence, the amount of lux needed in each of the facilities to ensure users comfortability with the reading task is 500 lux. This amount of lux when multiplied by the area of the facility considered would give the light flow needed [28]. Therefore, to determine the number of light fittings required in conformity to IALD [29] standard, it is expressed mathematically as in Equation (14).

$$N = \frac{E \times A}{F \times UF \times LLF} \tag{14}$$

Where, N is the Number of Fittings**,** E is the Lux Level Required on Working Plane**,** A is the Area of Room
F is the total luminous flux (Lumens) from all the Lamps in one fitting, UF is the Utilisation Factor and LLF is the Light Loss Factor

The utilization factor UF is depended on the Room Index, K, which depends on the facility's dimensions and the kind of lighting system and can be determined using Equation (15). The Equations (14) and (15) was adopted from FL [30] and PC [31].

$$\text{Room Index, } K = \frac{L \times W}{H_m (L+W)} \qquad (15)$$

Where, L is the Room Length**,** W is the Room Width
H_m is the Mounting Height of Fitting from working plane i.e. Desk or Bench Height.
The value of Utilisation Factor to be used in Equation (14) can be obtained from Table 1 using the value of the room index K and the room reflectance.

The reflectance factors (see column 1-3 of Table 1) is the ability of various materials and finishes to reflect light for ceiling, walls and floor. The working plane (height of a work-desk) is where the most important tasks in the space are performed and is often set at 0.85 m. The typical reflectance factor values for various building applications are available in literature [30].

Table 1: Utilisation Factor values in respect of room index and room reflectance

UTILISATION FACTOR												
ROOM REFLECTANCE			**ROOM INDEX**									
Ceiling	**Wall**	**Floor**	**0.75**	**1.00**	**1.25**	**1.50**	**2.00**	**2.50**	**3.00**	**4.00**	**5.00**
	0.50		0.44	0.49	0.52	0.55	0.57	0.59	0.60	0.62	0.63
0.70	**0.30**	**0.20**	0.41	0.46	0.50	0.52	0.55	0.57	0.59	0.60	0.62
	0.10		0.39	0.44	0.48	0.50	0.53	0.56	0.57	0.59	0.61
	0.50	**0.20**	0.43	0.48	0.51	0.53	0.56	0.57	0.58	0.60	0.61
0.50	**0.30**		0.41	0.46	0.49	0.51	0.54	0.56	0.57	0.58	0.60
	0.10	**0.20**	0.39	0.44	0.47	0.49	0.52	0.54	0.56	0.58	0.59
	0.50		0.43	0.47	0.50	0.52	0.54	0.56	0.57	0.58	0.58
0.30	**0.30**	**0.20**	0.40	0.45	0.48	0.50	0.53	0.54	0.55	0.57	0.58
	0.10		0.38	0.43	0.46	0.49	0.51	0.53	0.54	0.56	0.57
0.00	**0.00**	**0.00**	0.37	0.42	0.45	0.47	0.50	0.51	0.52	0.53	0.54

Source: FLD [25].

The Light Loss Factor/ Maintenance Factor (LLF/MF) takes account of the depreciation over time of lamp output and dirt accumulation on the fitting and walls of the building. Typical Light Loss Factor values for various buildings application is shown in Table 2.

Table 2: Typical Light Loss Factor (LLF/MF) values

	LLF Values
Air Conditioned Office/Building	0.8
Clean Industrial Building	0.7
Dirty Industrial Building	0.6

Source: FL [30].

2.3 Energy Savings Analysis

Having calculated the number of light fitting of a particular specification and the air conditioning system capacity required for each of the facilities considered, the energy expended and cost implication were determined using Equations (16) and (17) respectively. The office working hours is set as 8 hours (8 am - 4 pm) and the cost of electricity is ₦ 31.27 k per kWh. A Value Added Tax (VAT) of 5 % of the total cost of energy consumed is added as obtained in Nigeria. Therefore,

$$\text{Total Electric Power Expended (kWh)} = \text{Wattage} \times \text{Working hours} \qquad (16)$$

$$\text{Total Cost of Electric Power Expended (₦)} = (\text{Total Electric Power Expended} \times \text{Cost of Electricity}) + \text{Value Added} \qquad (17)$$

III. Results and Discussions

Tables 3-5 shows the variation of average room temperature while Tables 6-8 shows the variation of average illuminance, measured over one month, for the investigated facilities. These data gave a picture of how the efficiency of the building facilities stands as per their design. When compare with the standard value of 20 ^oC to 23 ^oC indoor temperature and 350-500 lux illuminance required for thermal comfort and adequate lighting respectively regarding the sedimentary and/or reading task being carried out within the facilities, it is obvious that the indoor temperature fall outside (i.e. above) the range of conducive indoor temperature for most of the facilities and the working hours of the day. This indicates that mechanical ventilation (air conditioning) system would always be required to maintain thermal comfort in most of the facilities. However, in very few of the facilities, particularly between the hours of 8.00 to 11.00, the average indoor temperature is within the Industrial Thermal standard for sedimentary working condition. This was found in facilities provided with ample windows and/or openings for proper airflow according to their design as well as those adequately located for proper airflow so that natural ventilation is encouraged.

The Illuminance measured also fall below the industrial standard for most of the investigated facilities while some few facilities measured up to the standard taken the advantage of the natural light of the day. In fact, the higher the level of facilities within the building investigated the higher the illuminance. Also, the illuminance values are higher towards the afternoon due to the effect of sunshine. Improvement in the value of illuminance of the facilities was noted to be a function of their location within the building, size of their windows/openings and their closeness to source of light and the indoor paints used for the facility.

Table 3: Variation of average indoor temperature over one month of facilities investigated on the ground floor of SEET building, FUTA (^OC)

Facility Type	Orientation	Time (Period of the day)								
		08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
Office 1	North	26	26	27	28	28	28	29	30	30
	South	26	27	27	28	30	28	29	29	28
Office 2	North	25	25	26	26	27	28	26	25	26
	South	24	24	25	25	26	26	26	24	24
Office 3	North	25	25	26	26	27	28	26	25	26
	South	24	24	25	25	26	26	26	24	24
Office 4	North	25	25	26	26	27	28	26	25	26
	South	24	24	25	25	26	26	26	24	24
Laboratory 1	North	24	24	25	25	26	27	26	24	25
	South	25	24	26	25	26	26	26	24	24

Table 4: Variation of average indoor temperature over one month of facilities investigated on the first floor of SEET building, FUTA (OC)

Facility Type	Orientation	Time (Period of the day)								
		08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
Office 1	North	25	25	26	26	27	28	26	27	25
	South	22	22	23	24	25	27	26	25	23
Office 2	North	25	25	26	26	27	28	26	25	26
	South	22	23	25	25	26	26	26	24	23
Office 3a	North	23	22	25	26	27	28	26	27	26
	South	21	22	22	23	25	26	27	27	25
Office 3b	North	24	24	25	25	26	26	26	24	24
	South	24	24	25	25	26	27	26	25	25
Office 4	North	25	26	27	26	27	27	26	25	25
	South	22	23	26	25	25	26	25	23	24
Lecture Room 1	North	21	21	22	23	25	27	26	26	24
	South	22	21	23	23	26	26	26	24	23
Lecture Room 2	East	22	22	21	24	25	27	27	26	24
Computer Room	West	23	23	24	26	27	28	26	26	25

Table 5: Variation of average indoor temperature over one month of facilities investigated on the second floor of SEET building, FUTA (^OC)

Facility Type	Orientation	Time (Period of the day)								
		08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
Office 1	North	24	25	27	27	28	28	27	27	25
	South	25	25	26	26	27	28	26	27	26
Office 2	North	23	25	25	26	28	27	28	27	25
	South	22	22	23	26	27	26	26	25	24
Office 3a	North	23	22	24	26	28	29	28	27	27

	South	23	23	24	26	28	27	26	27	25
Office 3b	North	25	26	27	27	29	28	29	28	26
	South	25	25	26	26	25	26	26	26	24
Office 4	N-West	23	25	26	27	28	28	28	27	27
	S-West	23	24	25	26	26	25	26	24	24
Conference Room	East	22	23	25	27	27	26	26	24	23
Library	West	24	25	26	26	27	27	26	27	26

Table 6: Variation of average illuminance over one month of facilities investigated on the ground floor of SEET building, FUTA (lux)

Facility Type	Orientation	Time (Period of the day)								
		08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
Office 1	North	74	80	77	88	104	116	112	90	89
	South	78	83	88	99	130	107	110	105	88
Office 2	North	73	74	75	77	75	75	78	80	81
	South	79	82	79	87	109	110	122	116	105
Office 3	North	70	70	72	73	77	79	80	78	75
	South	77	82	84	83	78	93	91	93	87
Office 4	North	74	76	75	83	90	100	80	85	78
	South	75	76	70	97	120	100	96	90	82
Laboratory 1	North	75	74	88	79	98	99	102	105	84
	South	81	83	80	98	117	114	98	103	87

Table 7: Variation of average illuminance over one month of facilities investigated on the first floor of SEET building, FUTA (lux)

Facility Type	Orientation	Time (Period of the day)								
		08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
Office 1	North	103	102	104	108	123	125	113	110	102
	South	262	284	295	320	322	310	296	289	277
Office 2	North	98	102	105	107	112	108	103	107	103
	South	137	151	157	176	187	195	204	182	168
Office 3a	North	103	104	90	115	131	124	112	110	106
	South	100	103	116	131	155	147	119	113	114
Office 3b	North	146	151	185	196	201	208	188	173	169
	South	249	258	281	298	315	331	307	292	275
Office 4	North	98	101	99	104	112	109	105	106	107
	South	117	128	116	125	137	141	147	113	112
Lecture Room 1	North	312	341	350	359	352	357	361	351	337
	South	517	521	522	536	564	549	543	537	525
Lecture Room 2	East	786	794	805	818	833	842	836	845	804
Computer Room	West	299	306	318	313	326	348	335	328	316

Table 8: Variation of average illuminance over one month of facilities investigated on the second floor of SEET building, FUTA (lux)

Facility Type	Orientation	Time (Period of the day)								
		08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
Office 1	North	547	558	572	579	591	599	589	577	572
	South	555	562	573	582	588	604	608	598	582
Office 2	North	173	187	202	214	217	236	241	233	224
	South	212	228	243	255	272	277	261	249	236
Office 3a	North	206	218	225	239	252	244	248	241	232
	South	210	221	237	252	268	261	250	238	231
Office 3b	North	271	278	287	306	317	325	313	302	291
	South	318	334	343	351	359	371	352	344	331
Office 4	N-West	124	130	157	177	180	180	167	162	154
	S-West	128	137	168	180	188	192	201	180	170
Conference Room	East	649	656	668	683	695	707	702	694	685
Library	West	342	348	360	365	376	367	358	347	331

Tables 9, 10 and 11 shows the summary of the load estimation, capacity of air conditioning required and total cost of energy to be used in the facilities investigated at the ground floor, first floor and second floor respectively. Also, Tables 12, 13 and 14 shows the Lighting Requirement, Energy Expended and Cost of Energy required to lighting the facilities investigated at the ground floor, first floor and second floor respectively. The Tables reveal the energy to be expended by the air conditioning systems and the lighting systems based on the load estimation and lighting requirements of the facilities as calculated using Equations (1) - (17). The energy would have to be expended and paid for if the facilities are to use the air conditioning and the lighting systems to achieve comfort within the facilities throughout the working period.

The total cost of energy, on the Tables, is the amount required to run the standard air conditioning system and/or the lighting system required for the investigated facilities for an eight hours working day. This would amount to N27,777:14 K ($77.78) to ensure thermal comfort and N4,286:74K ($12) to ensure adequate lighting for the users of the facilities for a day. However, if some of the features of the facilities, discussed earlier, could be designed from the outset to encourage the efficient use of natural ventilation as well as natural lighting for at least half or all of the working hours, so that the mechanical systems can be put off, then the associated cost values of between N13,888:57K ($38.89) to N27, 777:14K ($77.78) for the air conditioning systems and between N2, 143:37K ($6) to N4, 286: 74K ($12) for the lighting systems can be saved. This would amount to a total of between N 16,031: 94K ($44.89) to N 32, 063.88K ($89.78) which could be saved in a day. This amount, if aggregated over the entire facilities within the SEET building and over the entire buildings within FUTA community, for example, would result in a substantial/huge savings over days, months and years.

Table 9: Load Estimation, Energy Expended and Cost of Energy to run the Air Conditioning System of the Facilities Investigated at the Ground Floor

Facility Type	Orientation	Sensible Heat Load (W)	Latent Heat Load (W)	Total Heat Load (W)	Capacity of A/C (Ton)	Selected A/C Power Input (Horse power)	Energy Consumed (kWh)	Total Cost of Energy for the 8 hours period (₦.K)
Office 1	North	3285.6	2722.5	6608.91	2	2	1.5	394.00
	South	3156	2722.5	6466.35	2	2	1.5	394.002
Office 2	North	3296.9	2722.5	6621.34	2	2	1.5	394.002
	South	3167.3	2722.5	6478.78	2	2	1.5	394.002
Office 3	North	3609.7	2722.5	6965.42	2	2	1.5	394.002
	South	3901.3	2722.5	7286.18	2	2	1.5	394.002
Office 4	North	3764.4	2722.5	7135.59	2	2	1.5	394.002
	South	3678	2722.5	7040.55	2	2	1.5	394.002
Laboratory 1	North	12280.6	10775	25361.16	7	7	5.25	1379.007
	South	12474.6	10775	25574.56	7	7	5.25	1379.007

Table 10: Load Estimation, Energy Expended and Cost of Energy to run the Air Conditioning System of the Facilities Investigated at the First Floor

Facility Type	Orientation	Sensible Heat Load (W)	Latent Heat Load (W)	Total Heat Load (W)	Capacity of A/C (Ton)	Selected A/C Power Input (Horse power)	Energy Consumed (kWh)	Total Cost of Energy for the 8 hours period (₦.K)
Office 1	North	4067.1	2822.5	7578.56	2	2	1.5	394.002
	South	4131.9	2822.5	7649.84	2	2	1.5	394.002
Office 2	North	4143.2	2822.5	7662.27	2	2	1.5	394.002
	South	4078.4	2822.5	7590.99	2	2	1.5	394.002
Office 3a	North	5025.1	2822.5	8632.36	2	2	1.5	394.002
	South	5219.5	2822.5	8846.20	2	2	1.5	394.002
Office 3b	North	3361.7	2822.5	6802.62	2	2	1.5	394.002
	South	3264.5	2822.5	6695.70	2	2	1.5	394.002
Office 4	North	4128.7	2822.5	7646.32	2	2	1.5	394.002
	South	4128.7	2822.5	7646.32	2	2	1.5	394.002
Lecture Room 1	North	17650.1	16800	37895.11	10	10	7.5	1970.01
	South	17941.8	16800	38215.98	10	10	7.5	1970.01
Lecture Room 2	East	18186.1	12575	33837.21	10	10	7.5	1970.01
Computer Room	West	20101.1	12575	35943.71	10	10	7.5	1970.01

Table 11: Load Estimation in Office, Energy Expended and Cost of Energy to run the Air Conditioning System of the Facilities Investigated at the Second Floor

Facility Type	Orientation	Sensible Heat Load (W)	Latent Heat Load (W)	Total Heat Load (W)	Capacity of A/C (Ton)	Selected A/C Power Input (Horse power)	Energy Consumed (kWh)	Total Cost of Energy for the 8 hours period (₦.K)
Office 1	North	5674.1	2822.5	9346.26	3	3	2.25	591.003
	South	5738.9	2822.5	9417.54	3	3	2.25	591.003
Office 2	North	5750.2	2822.5	9429.97	3	3	2.25	591.003
	South	5685.4	2822.5	9358.69	3	3	2.25	591.003
Office 3a	North	7435.6	2822.5	11283.91	3	3	2.25	591.003

	South	7630	2822.5	11497.75	3	3	2.25	591.003
Office 3b	North	4968.7	2822.5	8570.32	2	2	1.5	394.002
	South	4871.5	2822.5	8463.40	2	2	1.5	394.002
Office 4	North West	4128.7	2822.5	7646.32	2	2	1.5	394.002
	South West	4128.7	2822.5	7646.32	2	2	1.5	394.002
Conference Room	East	23723.9	23200	51616.29	15	15	11.25	2955.015
Library	West	21028.7	12725	37129.10	10	10	7.5	1970.01

Table 12: Lighting Requirement, Energy Expended and Cost of Energy to Lighting the Facilities Investigated at the Ground Floor

Facility Type	**Orientation**	**No of Fixture Required Standard (Compact Fluorescent)**	**Illuminance Required Standard (Lux)**	**Total Wattage (W)**	**Energy Consumed (kWh)**	**Total Cost of Energy for the 8 hours period (₦.K)**
Office 1	North	3	500	255	0.255	66.98034
	South	3	500	255	0.255	66.98034
Office 2	North	3	500	255	0.255	66.98034
	South	3	500	255	0.255	66.98034
Office 3	North	3	500	255	0.255	66.98034
	South	3	500	255	0.255	66.98034
Office 4	North	3	500	255	0.255	66.98034
	South	3	500	255	0.255	66.98034
Laboratory 1	North	12	500	1020	1.02	267.9214
	South	12	500	1020	1.02	267.9214

Table 13: Lighting Requirement, Energy Expended and Cost of Energy to Lighting the Facilities Investigated at the First Floor

Facility Type	**Orientation**	**No of Fixture Required Standard (Compact Fluorescent)**	**Illuminance Required Standard (Lux)**	**Total Wattage (W)**	**Energy Consumed (kWh)**	**Total Cost of Energy for the 8 hours period (₦.K)**
Office 1	North	3	500	255	0.255	66.98034
	South	3	500	255	0.255	66.98034
Office 2	North	3	500	255	0.255	66.98034
	South	3	500	255	0.255	66.98034
Office 3a	North	4	500	340	0.34	89.30712
	South	4	500	340	0.34	89.30712
Office 3b	North	3	500	255	0.255	66.98034
	South	3	500	255	0.255	66.98034
Office 4	North	3	500	255	0.255	66.98034
	South	3	500	255	0.255	66.98034
Lecture Room 1	North	16	500	1360	1.36	357.22848
	South	16	500	1360	1.36	357.22848
Lecture Room 2	East	12	500	1020	1.02	267.92136
Computer Room	West	12	500	1020	1.02	267.92136

Table 14: Lighting Requirement, Energy Expended and Cost of Energy to Lighting the Facilities Investigated at the Second Floor

Facility Type	**Orientation**	**No of Fixture Required Standard (Compact Fluorescent)**	**Illuminance Required Standard (Lux)**	**Total Wattage (W)**	**Energy Consumed (kWh)**	**Total Cost of Energy for the period of 8 hours (N . K)**
Office 1	North	3	500	255	0.255	66.98034
	South	3	500	255	0.255	66.98034
Office 2	North	3	500	255	0.255	66.98034
	South	3	500	255	0.255	66.98034
Office 3a	North	4	500	340	0.34	89.30712
	South	4	500	340	0.34	89.30712
Office 3b	North	3	500	255	0.255	66.98034
	South	3	500	255	0.255	66.98034
Office 4	North West	3	500	255	0.255	66.98034
	South West	3	500	255	0.255	66.98034

Conference Room	East	12	500	1020	1.02	267.9214
Library	West	12	500	1020	1.02	267.9214

IV. Conclusion and Recommendations

Saving energy usage in building can help to reduce the energy bills, in addition to reducing pollution. The analysis in this study was used to assess and establish ways by which the energy usage of a building can be reduced through energy saving approach and it was revealed that energy can be saved due to proper design and selection of relevant features (e.g. roof, window/door openings, glass, block materials, paints, etc) of the building facilities. Energy cost could be saved based on the effective utilization of natural ventilation and lighting during the day while planning the design of the building (at the design phase) to provide adequate ventilation and illumination for its various facilities (offices, laboratories etc). Therefore the following suggestions are recommended:

i) Appropriate design of features of building facilities should be encouraged towards adequate utilization of natural ventilation and lighting;
ii) Effort should be made to investigate the effect of features of building facilities on the feasibility of using natural source to achieve adequate ventilation and lighting of such facilities for human users comfort during the work hours; and
iii) Effort should be made to provide tools and/or means for exhaustive assessment of building facilities' features towards achieving designs that would ensure adequate ventilation and lighting without using mechanical ventilation and lighting systems, all the time, thereby facilitating reduction of buildings energy cost.

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