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Low Energy Design of Buildings in the Tropics; The Case of Lagos, Nigeria

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ABSTRACT
The paper presents an argument for the provision of air conditioning in office and residential developments in Lagos, Nigeria while noting the international drive for energy conservation and sustainability. An historical perspective of natural ventilation and mechanical cooling is given. Also the outcome of recent studies regarding the comfort criteria for Lagos is discussed. Proposals are proffered for low-energy design of buildings.

KEYWORDS: *Low-energy design, cooling comfort and warm humid climate.*

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I. INTRODUCTION

One of the main functions of a building is to protect the occupants against harsh outdoor climate and to provide a comfortable and healthy environment for these occupants that would impact on their productivity and performance. One of the parameters that impact on the satisfaction of the occupant and which is of relevance to us is thermal comfort. Thermal comfort is defined by ASHRAE as "the state of mind that expresses satisfaction with the surrounding environment[1]. Since 'satisfaction' is a subjective feeling, the intention would be to minimise the percentage of 'dissatisfied' occupants.
Factors that determine thermal comfort include[2]:

a) Air temperature
b) Mean radiant temperature
c) Air movement (velocity)
d) Relative humidity
e) Clothing
f) Activity level

It is now up the Architect and the Engineers to provide the 'right' internal environment by the interplay of the first four factors above (referred to as climatic or thermal factors). The last two factors are personal to the occupant. In providing a comfortable environment, consideration has to be given to the important issues of global warming and sustainability. Global warming, or specifically global climate change, is the most high-profile and urgent sustainability issue[3]. The Inter-governmental Panel on Climate Change (IPCC) has indicated in its report that warming of the (world) climate system is unequivocal and that world temperatures could rise by between 1.1 and 6.4^{o}C during the 21st century[4]. The cause has been attributed to the 'observed increase in anthropogenic (human) green house gas concentrations[5].' To mitigate the problem, the practice of sustainable developments has taken a front seat. Sustainable development is that which meets the needs of the present without compromising the ability of future generations to meet their own needs[6]. To this end, sustainable design for thermal comfort seeks to minimise the energy consumption of ventilation and heating/cooling systems.

This paper gives an argument for the use of air-conditioning as a necessity for thermal comfort in a warm humid climate like that of Lagos. Since the use of air-conditioning is inevitable the emphasis then shifts to the provision of low-energy designs for buildings. "An energy efficient design aims to provide thermal comfort and acceptable indoor air quality with the minimum use of energy. Mechanical ventilation is a primary energy intensive process, and air conditioning is even more so. Therefore, an energy efficient building will provide the desired internal conditions by relying on natural means where possible."[7]

II. THE ARGUMENT FOR AIR-CONDITIONING IN LAGOS

Lagos is the commercial capital of Nigeria and is located on latitude 06°27[1]N and longitude 03°24[1]E. It lies on the Atlantic Coast in the Gulf of Guinea. According to the much contested national census of 2006, the population of Lagos is put at 7,937,932 inhabitants[8]. Expectation is that the actual figure should be about 30 – 40% higher. The average population density is 7,941 inhabitants per km^2. The hottest months are February and March with mean temp of 29°C. The table below gives trend in temperature for the years 1993 to 2007.

Table 1:- Maximum and minimum mean temperature in Lagos (1993 – 2002)[9]

YEAR	MONTH	Max Temp °C	Min Temp °C
1993	March	33	25
1994	March	33	27
1995	April	33	24
1996	April	33	27
1998	March	35	26
1999	Feb	34	25
2000	Feb	35	25
2001	Feb	34	23
2002	Feb	34	23

Source - Nigeria Meteorological Services, Oshodi, Nigeria

Lagos has a warm humid climate with a dust laden atmosphere (especially during the harmattan season) and a significant amount of air-borne pollution. The main dry season (November to February) is accompanied by harmattan winds which bring dusty haze from the Sahara Desert. Noise pollution emanates from the gleeful communities and boisterous drivers on Lagos roads.The 2007 monthly range of temperature for Ikeja, Lagos is indicated in the chart below. The minimum temperatures usually occur between the evenings and the early mornings.

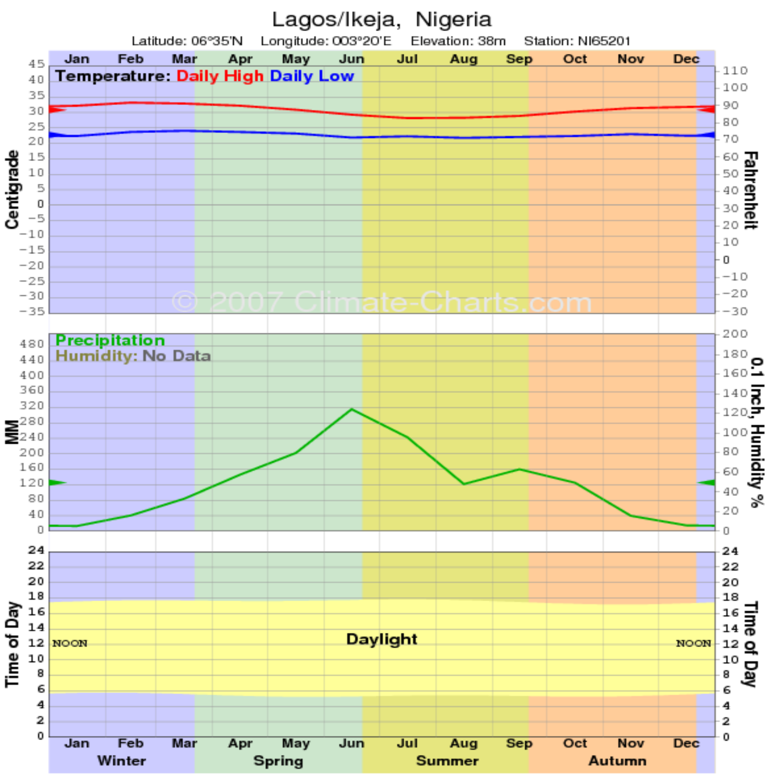

Figure 1:- Weather data for Ikeja, Lagos[10]

A typical heat gain calculation for an office building in Lagos should give a cooling load of 175 - 250W/m^2. That for a residential apartment gives 100 – 175W/m^2. Using these rates, an appropriate ventilation system can be chosen based on the strategy for selecting the ventilation system presented in the CIBSE AM10 (2005) publication. Since a seasonal mixed mode system is not acceptable as there is no appreciable drop in the rates, the strategy is for full airconditioning.

The figure is presented below:

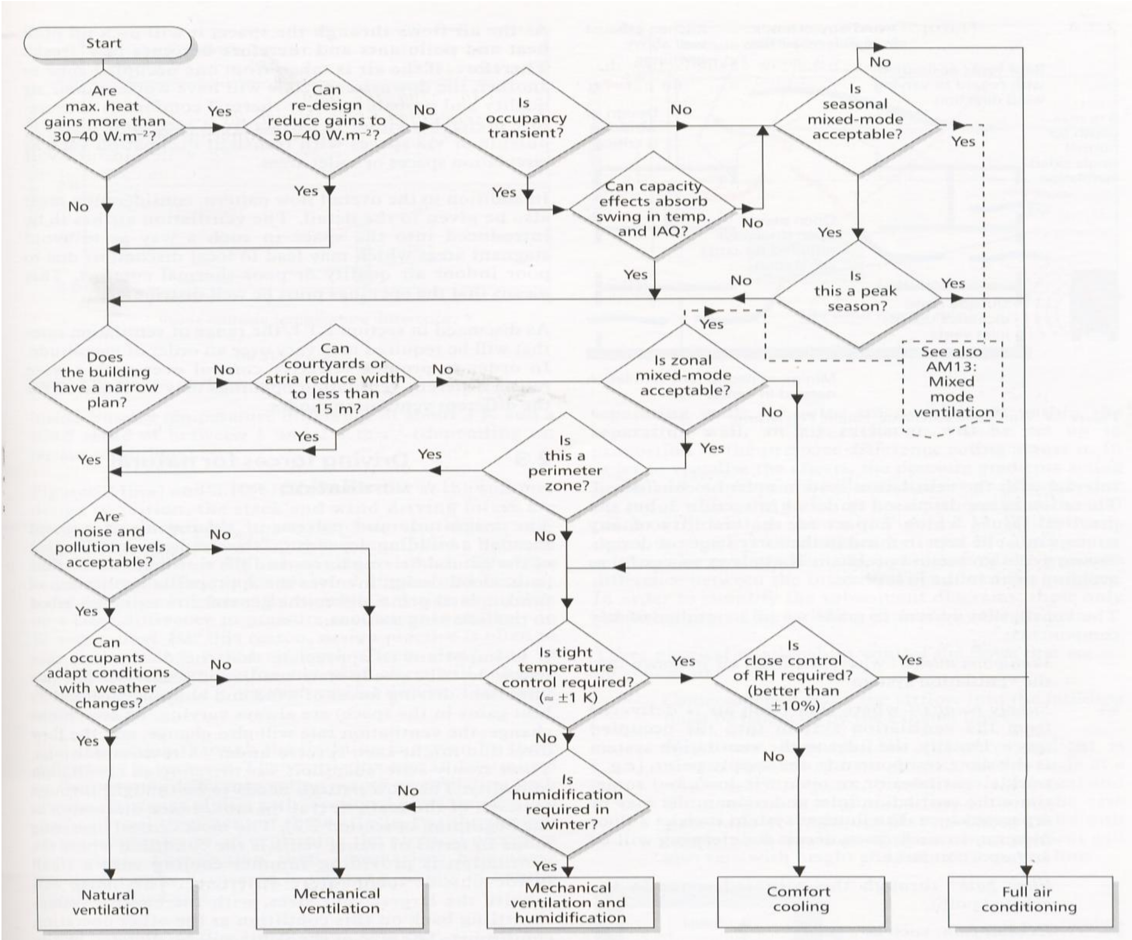

Figure 2:- Selecting a ventilation strategy[11]

Also according to CIBSE Guide A, the summer operative temperature range for airconditioned offices is 22 – 24^{o}C and for airconditioned residences 23^{o} – 25^{o}C. For non-airconditioned offices and dwellings the indoor comfort temperature is 25^{o}C (with a benchmark maximum of 28^{o}C).[12] Relating these comfort temperatures to the outdoor temperatures in the Table 1 and Figure 1 above, it is obvious that the choice should be for air conditioning. The choice of a mixed mode system may be possible for buildings during 'cold' nights.The choice of air conditioning is also strengthened by the problem of the dust laden atmosphere of Lagos and the prevalent noise and vehicular pollution in the high density communities and commercial areas of the city.

The IPCC Report listed barriers to adopting building technologies and practices that reduce GHG (green house gas) emissions[13]. With regards to Lagos, these include:

1. **Limitation of the traditional building design** – Local architects desire to design buildings that are prominent in style and size. These in most cases mean complex designs that inevitably require air conditioning.

2. **Energy subsides** – The cost of diesel in the UK is about 110p/litre. In Nigeria, diesel is the predominant fuel for power generation and it cost 42p/litre. Unfortunately the cost of construction in Nigeria is of a much higher percentage than in the UK. As such, the investor is not economically encouraged to expend additional funds on energy conservation.

3. **Culture, behaviour and lifestyle** – In the 1950s to early 1970s, air conditioning was perceived as a status symbol. Following the oil boom of the mid 1970s, the disposable income increased and air conditioning has been accepted as a standard. The absence of airconditioning is perceived to mean and would give a devalued assessment of a building.

III. CONSTRUCTION IN NIGERIA – A HISTORICAL PERSPECTIVE

Considering a warm humid climate like that of Lagos is airconditioning a luxury or a necessity? Given the relatively low rise in ambient temperatures over the years, how did the citizens cope prior to the introduction of mechanical cooling? In the 1860s, the Governor Lagos Colony complained that it was so hot and 'sticky' in Government House on some nights, that he would meet other members of his staff with pillows under their arms walking along the verandas in the middle of the night trying to find a cool spot. Buildings then were generally prefabricated and employed timber and corrugated iron. Mary Kingsley, a regular visitor to the West Coast of Africa, found these buildings 'as dark as ignorance', and when it rained on the 'tin roofs', totally uninhabitable. Another Colonial administrator, Lugard made a more successful effort in the design and specifications for these buildings. 100 years later non-indigenes could live healthy lives but alleviation of the heat in buildings had been only partially solved. Air movement assisted by the hand operated punka had given way to the ceiling fan and Lagos being one of the first cities in the world to have electricity in 1890, could take advantage of this invention.With the shift towards independence, particularly in tropical colonies, and the adoption of western norms of working, newcomers, expatriates particularly, sought better solutions to their living and working environments demanding realistic solutions to improve comfort conditions. This was not only for themselves but their indigenous counterparts. Young architects with new ideas were very welcome and using modern construction tempered by lessons learnt from indigenous traditional construction produced a higher degree of comfort in the buildings. This was easier in the hot dry climate of the north of the country. However in the south, where there is little difference between night and day temperatures and humidity is high, there is a limit to what can be achieved by natural conditioning and too much air movement can produce a 'chill' factor sufficient to cause 'colds' and fever. In the 50s and 60s mechanical cooling other than by ceiling fans was not an option because it was expensive with no facilities for maintenance.

Being a colonial territory at the time these changes were taking place, one of the most influential sources of information was the Building Research Station at Watford and the well established research of Thomas Bedford. The useful BRE research papers incorporated the thinking of many contemporary workers in the field. These include people such as Maxwell Fry and Jane Drew who published their first book, "Tropical Architecture in the Humid Zone"[14] and Ian Small and his team at the West African Building Research Institute in Ghana. However, still much of the resulting design depended upon empirical values, only later rationalised in the 'Manual of Tropical Housing and Building'[15] which was a comprehensive summary of known wisdom when it was published in 1974. In 1966 an important opportunity presented itself to specify building structures to meet climatic needs by the commissioning of a team to implement the First International Development Education Project in Nigeria. The terms of reference, significantly included the setting up of basic design and construction criteria for the project throughout Nigeria. Included in the team was Carl Mahoney who brought a scientific approach to the work and later devised the 'Mahoney Tables' largely from the result of this project.
While it was found that it was possible to design and construct buildings within suitable performance parameters there remained the question of establishing the parameters of 'comfortable' conditions under various activities of work and rest, taking into account the effects of acclimatisation, cultural habits, and physiological and psychological reactions. Indeed over the last 60 years or so, and certainly from the time that Bedford started his work, there have been many attempts to establish a single scale which covers the four variables in body heat gain namely: evaporation, radiation, convention and conduction. On the whole the Corrected Effective Temperature (CET) scale is considered the best understood.

Following the comprehensive IDA 1966 of 1966 and the assessment made in the terminal report 11 years later, the following comments and proposals emerged.
Many of the thermal comfort standards were uncontroversial and were already understood by the architects who had experience of the local environment.

- That the buildings were correctly oriented for breeze penetration in humid seasons or climates.
- That the buildings had limited solar penetration and also had valid roof insulations. (In the northern regions, double roof construction was employed).
- That the walls were painted with light reflective colours.

In 1988 a national seminar entitled 'Architecture, Climate and the Environment' was organised by the Nigerian Building and Road Research Institute. In a paper presented by J. Godwin[16], it was suggested that on the whole Nigeria enjoys a good climate which could be described as equable, having no extremes of heat and cold. But while natural controls are operable in the rural areas, in urban areas artificial solutions have become a necessity. It queried the comfort zones established in the Koenigsberger Manual and called for more evidence through subjective voting to establish comfort indices for acclimatised people in Nigeria and in the various climatic zones. New parameters were proposed which were lower in the upland locations such as the Jos and

Mambilla Plateaus. It was further suggested that at the lower end of the habitation scale such as low income housing, the 'ad hoc' approach to design was not contributing to the health and efficiency of the people. The paper called for more studies.

IV. NATURAL VENTILATION AND THERMAL COMFORT IN LAGOS

A study was carried out by Adebamowo[17] in November 2003 to confirm the thermal comfort in residential buildings with natural ventilation. The study used three existing housing units at three different locations of Lagos:

- Festac Town - a high density location
- University of Lagos Campus - a medium density location
- Victoria Garden City - a low density location

It is to be noted that the housing unit at the University of Lagos campus was purposely designed as a low-energy building. The orientation had the glazed elevations in the North-South orientation. There were effective shading devices and cross ventilation (evident by the high air velocity). The roof space was well insulated. The results are given in the tables below.

TERMS

$T_{OD}{}^0C$ - outdoor (ambient) dry bulb temp
$T_{OW}{}^0C$ - outdoor (ambient) wet bulb temp
$T_{RD}{}^0C$ - room dry bulb temperature
$T_{RW}{}^0C$ - room wet bulb temperature
GT^0C - globe temperature
MRT^0C - mean radiant temperature
CET^0C - corrected effective temperature
OT^oC - operative temperature
$RH_O\%$ - outdoor relative humidity
$RH_R\%$ - room relative humidity
Air Vel - Room air velocity

Table 2:- Thermal conditions in naturally ventilated dwellings in Festac, VGC and Unilag

CASE STUDY 1: 3-BEDROOM SEMI-DETACHED HOUSE AT HOUSE 22, I CLOSE 5TH AVENUE FESTAC TOWN												
Serial	Time	$T_{OD}{}^0C$	$T_{OW}{}^0C$	$RH_O\%$	$T_{RD}{}^0C$	$T_{RW}{}^0C$	$RH_R\%$	GT^0C	MRT^0C	Air Vel m/s	CET^0C	OT^0C
SITTING ROOM												
1	08.00hrs	29.5	26.0	74.0	30.0	26.0	72.0	30.3	30.5	0.3	27.1	30.2
2	10.00hrs	30.0	26.0	72.0	30.5	26.0	69.0	30.7	31.0	0.4	27.2	30.7
3	12.00hrs	30.5	25.5	67.0	31.5	26.0	64.0	31.8	32.0	0.4	27.7	31.7
4	14.00hrs	31.0	25.0	60.0	32.0	26.0	62.0	32.3	32.5	0.3	27.7	32.2
5	16.00hrs	30.5	25.5	67.0	31.5	25.5	61.0	31.7	32.0	0.4	27.7	31.7
6	18.00hrs	30.0	26.0	72.0	30.5	26.0	69.0	30.8	31.0	0.4	27.2	30.7
7	20.00hrs	30.0	26.0	72.0	30.5	26.0	69.0	30.8	31.0	0.4	27.2	30.7
BEDROOM												
1	08.00hrs	29.5	26.0	74.0	30.5	26.0	69.0	30.7	31.0	0.3	27.3	30.7
2	10.00hrs	30.0	26.0	72.0	31.0	26.0	67.0	31.3	31.5	0.3	27.5	31.2
3	12.00hrs	30.5	25.5	67.0	31.5	25.5	61.0	31.8	32.0	0.2	27.5	31.7
4	14.00hrs	31.0	25.0	60.0	32.0	26.0	62.0	32.3	32.5	0.2	27.8	32.2
5	16.00hrs	30.5	25.5	67.0	31.5	25.5	61.0	31.8	32.0	0.3	27.3	31.7
6	18.00hrs	30.0	26.0	72.0	31.0	26.0	67.0	31.2	31.5	0.3	27.5	31.2
7	20.00hrs	30.0	26.0	72.0	30.5	26.0	69.0	30.7	31.0	0.3	27.3	30.7
KITCHEN												
1	08.00hrs	29.5	26.0	74.0	31.0	26.0	67.0	31.2	31.5	0.2	27.8	31.2
2	10.00hrs	30.0	26.0	72.0	31.5	25.5	61.0	31.8	32.0	0.2	27.8	31.7
3	12.00hrs	30.5	25.5	67.0	32.0	26.0	62.0	32.2	32.5	0.2	28.2	32.2
4	14.00hrs	31.0	25.0	60.0	32.0	26.0	62.0	32.3	32.5	0.2	28.2	32.2
5	16.00hrs	30.5	25.5	67.0	31.5	25.5	61.0	31.7	32.0	0.2	27.8	31.7
6	18.00hrs	30.0	26.0	72.0	31.5	25.5	61.0	31.7	32.0	0.2	27.8	31.7
7	20.00hrs	30.0	26.0	72.0	31.0	26.0	67.0	31.3	31.5	0.2	27.8	31.2

CASE STUDY 2: 4-BEDROOM SEMI-DATCHED HOUSE AT HOUSE Q16, ROAD 47, VICTORIA GARDEN CITY, LEKKI, LAGOS												
Serial	Time	T_{OD} °C	T_{OW} °C	RH_O %	T_{ID} °C	T_{IW} °C	RH_i %	GT °C	MRT °C	Air Vel m/s	CET °C	OT °C
SITTING ROOM												
1	08.00hrs	29.5	26.5	78.0	30.0	26.0	70.0	30.2	30.5	0.4	26.9	30.2
2	10.00hrs	30.0	26.0	70.0	30.5	25.5	64.0	30.7	31.0	0.4	26.9	30.7
3	12.00hrs	30.5	25.5	64.0	31.5	26.0	62.0	31.8	32.0	0.3	27.6	31.7
4	14.00hrs	31.0	25.0	60.0	31.5	26.0	62.0	31.8	32.0	0.3	27.6	31.7
5	16.00hrs	30.5	25.5	64.0	30.5	25.5	64.0	30.7	31.0	0.4	26.9	30.7
6	18.00hrs	30.0	26.0	70.0	30.0	26.0	70.0	30.2	30.5	0.4	26.9	30.2
7	20.00hrs	29.5	26.0	74.0	30.0	26.0	70.0	32.0	30.5	0.4	26.9	30.2
BEDROOM												
1	08.00hrs	29.5	26.5	78.0	30.0	26.0	70.0	30.2	30.5	0.4	27.0	30.2
2	10.00hrs	30.0	26.0	70.0	30.5	26.0	68.0	30.7	31.0	0.4	27.0	30.7
3	12.00hrs	30.5	25.5	64.0	31.5	25.5	60.0	31.7	32.0	0.4	27.5	31.7
4	14.00hrs	31.0	25.0	60.0	32.0	26.0	60.0	32.3	32.5	0.4	27.0	32.2
5	16.00hrs	30.5	25.5	64.0	31.0	25.5	62.0	31.2	31.5	0.4	27.2	31.2
6	18.00hrs	30.0	26.0	70.0	30.5	26.0	68.0	30.7	31.0	0.4	27.2	30.7
7	20.00hrs	29.5	26.0	74.0	30.0	26.0	70.0	30.2	30.5	0.4	27.0	30.2
												0.0
KITCHEN												
1	08.00hrs	29.5	26.5	78.0	31.0	25.5	62.0	31.3	31.5	0.6	27.0	31.1
2	10.00hrs	30.0	26.0	70.0	31.0	25.5	62.0	31.3	32.5	0.6	27.0	31.4
3	12.00hrs	30.5	25.5	64.0	31.5	26.0	62.0	31.7	32.0	0.6	27.4	31.6
4	14.00hrs	31.0	25.0	60.0	32.0	26.0	60.0	32.2	32.5	0.6	27.6	32.1
5	16.00hrs	30.5	25.5	64.0	31.5	25.5	60.0	31.8	32.0	0.6	27.2	31.6
6	18.00hrs	30.0	26.0	70.0	30.5	25.5	64.0	30.7	31.0	0.6	27.0	30.6
7	20.00hrs	29.5	26.0	74.0	30.5	25.5	64.0	30.7	31.0	0.6	27.0	30.6

CASE STUDY 3: 4-BEDROOM TERRACE HOUSE AT UNIVERISTY OF LAGOS, AKOKA, LAGOS												
Serial	Time	T_{OD} °C	T_{OW} °C	RH_O %	T_{ID} °C	T_{IW} °C	RH_i %	GT °C	MRT °C	Air Vel m/s	CET °C	OT °C
SITTING ROOM												
1	08.00hrs	29.5	26.5	78.0	29.5	26.5	78.0	29.8	30.0	0.6	26.8	29.6
2	10.00hrs	30.5	25.5	68.0	30.0	25.5	68.0	30.2	30.5	0.6	26.5	30.1
3	12.00hrs	31.0	25.5	62.0	31.0	25.5	62.0	31.2	31.5	0.7	26.8	31.1
4	14.00hrs	31.5	25.5	60.0	31.0	25.5	62.0	31.2	31.5	0.7	26.8	31.1
5	16.00hrs	30.5	25.0	62.0	30.0	25.0	66.0	30.2	30.5	0.7	26.2	30.1
6	18.00hrs	29.5	26.0	74.0	29.5	26.0	74.0	29.7	30.0	0.7	26.5	29.6
7	20.00hrs	29.0	26.5	80.0	29.0	26.5	80.0	29.3	29.5	0.6	26.5	29.1
BEDROOM												
1	08.00hrs	29.5	26.5	78.0	29.5	26.5	78.0	29.8	30.0	0.6	26.8	29.6
2	10.00hrs	30.5	25.5	68.0	30.0	25.5	68.0	30.2	30.5	0.6	26.5	30.1
3	12.00hrs	31.0	25.5	62.0	31.0	25.5	62.0	31.2	31.5	0.7	26.8	31.1
4	14.00hrs	31.5	25.5	60.0	31.0	25.5	62.0	31.2	31.5	0.7	26.8	31.1
5	16.00hrs	30.5	25.0	62.0	30.0	25.5	66.0	30.2	30.5	0.7	26.2	30.1
6	18.00hrs	29.5	26.0	74.0	29.5	26.0	74.0	29.7	30.0	0.7	26.5	29.6
7	20.00hrs	29.0	26.5	80.0	29.0	26.5	80.0	29.3	29.5	0.6	26.5	29.1
KITCHEN												
1	08.00hrs	29.5	26.5	78.0	30.5	25.5	64.0	30.5	31.0	0.7	26.8	30.6
2	10.00hrs	30.5	25.5	68.0	31.0	25.0	60.0	31.3	31.5	0.7	26.8	31.1
3	12.00hrs	31.0	25.5	62.0	32.0	26.0	60.0	32.2	32.5	0.7	26.9	32.1
4	14.00hrs	31.5	25.5	60.0	32.0	26.0	60.0	32.3	32.5	0.7	26.9	32.1
5	16.00hrs	30.5	25.0	62.0	31.0	25.0	60.0	31.2	31.5	0.7	26.8	31.1
6	18.00hrs	29.5	26.0	74.0	30.5	25.5	64.0	30.7	31.0	0.7	26.8	30.6
7	20.00hrs	29.0	26.5	80.0	30.0	25.5	68.0	30.3	30.5	0.7	26.6	30.1

A review of the results shows that the operative temperatures for the three dwellings were higher than both the recommended 25°C and the peak of 28°C indicated in Tables 1.7 and 1.8 of the CIBSE Guide A (2006). Further analysis was carried out using the Corrected Effective Temperature (CET) of 30.5°C applicable for Nov 2003. The neutral temperature was calculated as 28.2°C. If the comfort band is taken as ±2.5°C, the minimum comfort level would be 25.7°C and the upper level would be 30.5°C. The limit for the relative humidity was 65%RH. The upper temp limit for the bedroom is usually 1°C lower than the neutral maximum. Using the CET parameters outlined above, the dwellings appeared to be comfortable only in the very early mornings and in the evenings (i.e. CET temp < 30.5°C). The building at the University of Lagos Campus gave the better result thereby justifying the mode of construction.The study was carried out with no form of mechanical ventilation. In answers to questions on comfort, most of the occupants responded that they felt slightly warm. Few responded to being neutral or warm. When asked how they had adapted to the environment, most answered that they had minimal clothing and had used hand fans during periods of 'seemingly' extreme discomfort. When the ceiling fans were turned on, none of the respondents felt warm and more people voted neutral than slightly warm.

V. CLIMATE CHANGE

The IPCC Report[18] indicated that the surface temperature for Lagos increased by about 1°C in the period between 1970 and 2004. It also predicted that in the last decade of the century (2090 – 2099), the temperature would increase by 3 - 3.5°C over the 2004 figures. Assuming a life-cycle of 25years for building constructions, it is in order to assume an increase of 1 - 1.5°C in the next 25years. What impact would this change have on present constructions? Would the buildings still meet the thermal comfort criteria? What would be the effect on energy consumption? What would be the consequence of increased energy usage on the environment? This, we believe, is justification for sustainability.
Architects and Engineers need to come up with building designs which meet the needs of the present while not compromising the ability of future generations to meet their own needs.

VI. PROPOSALS FOR ENERGY CONSERVATION

It has been shown from earlier sections that mechanical ventilation and airconditioning are not a luxury in Lagos but are indeed a necessity for the satisfaction and comfort of building occupants and users. Therefore the focus for the Architect and Engineer in Lagos is how to minimise the energy used for meeting the demands of thermal comfort.The basic methods for energy efficiency in buildings are well known and are already being used in designs. As such, the paper will only give a summary thus;

[1] Minimise the solar impact by providing adequate and appropriate shading. Care is to be taken that Lagos lies close to the equator and the sun rises and sets very low in the skies. The implication of this is that vertical shades are more effective and architects would need to come up with imaginative designs to meet their desires for spectacular constructions.
[2] Provide well insulated buildings in conformity with the British Building Regulation Part L.
[3] Optimise the selection of plants and equipments including operational controls.
[4] Enhance the building controls in order to minimise internal heat contributions from lighting and office equipment. 'Switch-off' can be a good strategy.
[5] Optimise the introduction of ventilation outdoor air and use carbon dioxide monitors. The energy used in cooling and dehumidification of outdoor air (for ventilation) is, most times, a significant proportion of the total building cooling load.
[6] Consider the use of natural ventilation (assisted by the use of ceiling and oscillating fans) in dwellings as an acceptable alternative to airconditioning. It may be necessary to keep the option of airconditioning for the extreme occasions.
[7] Use of renewable energies such as solar, thermal, wind and photovoltaic power systems.
As noted in the IPCC report, there are barriers to sustainable developments. These have to be addressed.

[1] Energy subsidy is a political issue for Nigeria. We are a major oil producer and how else can we benefit from this God-given resource if we have to pay the same price for fuel as the UK? With the subsidy in place, the capital cost of providing sustainability may not be encouraging to the developer.
[2] The interplay of lifestyle and culture would need to be studied further as it cannot be overlooked. Experience has shown that an American expatriate in Nigeria would leave the air-conditioner in his house permanently on even if he is away for a week. The European will only put on the unit when necessary. The Nigerian who can afford airconditioning will install one rather than tolerate discomfort.
[3] Corporate culture as exemplified in the business dress codes implies that room temperature set points are as low as 23°C ± 2°C. (This is the current design temp for commercial projects in Lagos as against the 24°C ± 2°C used in the 80s and 90s). Where less formal dressing is allowed, the design point can be raised to 25°C ± 2°C. There will be appreciable energy savings at this level. Also the efficiency of the refrigeration plants would be higher given the higher operating temperatures.

With regard to climate change, it has been predicted that the next 25years would witness a rise of 1 - 1.5^{o}C. Based on the adaptive model of thermal comfort[19], the neutral temp can 'comfortably' rise by 0.5 - 0.8^{o}C from the present 28^{o}C. However, the consequential rise in the cooling load is higher and there is bound to be discomfort and overheating in naturally ventilated buildings. There is no doubt that the use of air-conditioners in dwellings will increase. For commercial properties which are already airconditioned, it may be possible to raise the temperature set points. If the same plants are to be maintained, adaptive means would have to be employed to achieve comfort during the period between 10am to 4pm when the highest heat gains are expected.
And there is the lighter, non-technical side to the issue of energy conservation. We have pasted an extract from the ecological study on sustainability[20].

WASHINGTON — "Save water, shower together," young people proclaimed a few years ago.
It turns out they may have been right. Americans spend an extra $3.6 billion annually on water as a result of the extra households created when people divorce, Jianguo Liu, an ecologist at Michigan State University, estimated. In countries around the world divorce rates have been rising, and each time a family dissolves the result usually is two households, explained Liu, whose analysis of the environmental impact of divorce appears in this week's online edition of Proceedings of the National Academy of Sciences. "A married household actually uses resources more efficiently than a divorced household," said Liu. Households with fewer people are simply not as efficient as those with more people sharing, he added. A household uses the same amount of heat or air conditioning whether there are two or four people living there. One person or several use the same refrigerator. Two people living apart run two dishwashers instead of just one.

Per person, divorced households spent more per person per month for electricity, compared to a married household, as multiple people can be watching the same television, listening to the same radio, cooking on the same stove and or eating under the same lights. That means some $6.9 billion in extra utility costs per year, Liu calculated, in addition to the extra $3.6 billion for water, plus the other costs such as land use.In other words, Architects and Engineers may need to double the present target of conservation. As things stand, whatever is saved is being used up so that there is actually no net saving. The easier solution is, of course, to marry and shower together.

VII. CONCLUSION

The use of airconditioning in Lagos is inevitable. However attempts can and are being made to reduce the energy consumed by the system. Energy conservation is expected to remain the main focus even into the period of climate change.Professionals in the Built Environment need to work together in a holistic manner to ensure that all aspects of the building, including the building envelope, fabric, services and operational use of the Building Management Systems (BMS) function together to ensure good thermal performance with low-energy and low carbon emissions.

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