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THE CONCEPT OF THERMAL COMFORT IN THE BUILT ENVIRONMENT GIVEN THE CURRENT GLOBAL ECONOMIC CRISIS – A CASE STUDY OF LAGOS, NIGERIA

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Abstract

The global economic crisis that has gripped the world over the past years is not abating even as we go into 2012. The cost of energy has now gone up even in Nigeria that happens to be an oil producing nation. By virtue of the warm and humid climate in Lagos, the use of mechanical cooling to attain desired thermal comfort is common place. However air-conditioning uses energy and energy costs money. How then can we maintain comfortable working and living conditions for the majority in the face of dwindling wealth?

This paper discusses the concept of thermal comfort in the warm and humid climate of Lagos with a focus on the psychology of thermal comfort. Given the number of quantitative studies already carried out in similar environments, the study relied more on the qualitative aspect. A review of relevant literature is presented. The paper proffers suggestions as to how to ensure that people live comfortably and affordably.

Keywords: Thermal comfort, psychology, low-energy.

Introduction

> "Several challenges threaten progress towards sustainable development goals. The spike in food and energy prices in 2008 led to a severe food crisis. The subsequent fall of energy prices has eased some of the pressure on energy importing countries. Yet food prices remain high. The global financial and economic crisis in 2009 has exacerbated the situation. Growth rates are falling, unemployment is rising, poverty is deepening, hunger and malnutrition are on the increase again, and the achievement of the Millennium Development Goals is in jeopardy" (UN – DESA, 2009).

The quote above was made in 2009. In 2012, the news about the global economy is not better as growth and trade have slowed sharply (World Bank, 2012). Private and public debts are at enormous proportions that even countries like Ireland and Portugal had to be bailed out of the quagmire. More countries are tithering on the brink of financial collapse. The governor of the Bank of England was "definitely concerned by the squeeze on real living standards" (The Telegraph, 2011). The rising unemployment has left many households either without any or a significantly reduced income. In Nigeria, the national unemployment rate in 2011 was 23.9%, that is, up from 21.1% in 2010 and 19.7% in 2009 (National Bureau of Statistics, 2011). Much of the developed world has had to introduce stimuli to resuscitate the economy. Even then, the economic viability of this is doubtful and the general attitude is one of caution. "A debt-fuelled recovery from a debt-fuelled recession is a cause for concern" (The Telegraph, 2011).

It is generally assumed that one of the casualties of the economic crisis is the nation's standard of living or the wellbeing of the citizens. Those who depend solely on salary, who have children or a health problem, always tend to be worse off (Vaitilingam, 2009).
Even businesses have become frugal. In Nigeria, those who are still investing in the property market demand optimal value for money. Budget constraint is a major consideration and only essential provisions are being made. Luxury items or 'wish-to-haves' would have to be justified by savings in other areas. The cost of running business

also comes under scrutiny. This is profound in Nigeria because of the poor state of the infrastructure.

However, thermal comfort is still central to how people behave in the built environment and directly affects their sense of wellbeing and productivity. The perception of thermal comfort is an important aspect of the built environment when one considers that a person spends a greater part of the day indoors (Hoof et al, 2010).

How then can the individual (in Lagos) attain the desired or acceptable thermal comfort level at the least or optimal cost?

Thermal Comfort

> "Thermal comfort is that condition of mind that expresses satisfaction with the thermal environment" (ASHRAE, 2009).
>
> "The conscious mind appears to reach conclusions about thermal comfort and discomfort from direct temperature and moisture sensations from the skin, deep body temperatures, and the efforts necessary to regulate body temperatures" (Hensel 1973, 1981; Hardy et al., 1971; Gagge 1937; Berglund 1995).

The six basic factors that affect thermal comfort are:

- Air temperature
- Radiant temperature
- Air velocity
- Humidity
- Clothing
- Metabolic rate

The first four are termed the environment factors and the latter two are the personal factors. Interestingly Fanger (1972) and de Dear et al. (1991, 1997) found that for the same conditions of air velocity, humidity, clothing and metabolic rate, individuals in different climatic regions will experience thermal comfort within the same range of temperatures. As such thermal studies in Lagos and Mumbai should yield the same result under similar conditions.

It is to be noted that the two definitions of thermal comfort given above indicate that the perception of comfort is of the mind. In other words, comfort may be subjective. Put differently, there is a psychological side to comfort. Comfort can depend on one's emotions of satisfaction, expectations, pleasantries, joy or sadness, loneliness or aloneness, etc.

Based on 40 years of studies, Rholes (2007) was able to conclude that one's environmental preference is based on value judgments that are influenced by our backgrounds, socio-economic levels, age and invariably past experiences. The same feeling relates to lighting and music.

"Within the range of normally experienced lighting and thermal environments, comfort appears to be an elusive, and largely psychological, phenomenon. As designers of energy efficient buildings, we need to understand these psychological processes. With greater knowledge, we may be able to use psychology to expand the visual and thermal comfort zones, at little or no human or economic costs" (Heerwagen et al, 1984).

Heerwagen et al, (1984) advocated for more research that concentrate on the people and how feelings, motivations, perceptions, preferences and adaptations affect human responses to thermal and visual environments.

Nikolopoulou et al, (2003) made similar linkages between thermal comfort and psychological adaptation but this time for the outdoor urban spaces. Both the physical and psychological parameters accounted equally for the comfort evaluation of their subjects. Issues of naturalness (greenness); expectation (for the season or space); experience (short or long term); time of exposure; perceived control (in making choices); and environmental stimulation all contributed to the psychological adaptation of the individual. There was a wide difference between the actual result and the predicted result of the level of dissatisfaction based on the predicted mean vote model.

The same psychological approach was used in designing the interior of the Boeing 777 airplane (Boeing 2002). "Colours also can influence a person's perception of humidity, temperature and aroma. The colour orange will make one feel warmer; blue/green-cooler; green - moist; orange - dry; blue gives a perception of clean or fresh fragrance; pink – sweet. As such, the cabin wall patterns contributed to the passenger's sense of comfort."

Thermal Comfort for Lagos

Lagos lies on the Atlantic Coast in the Gulf of Guinea (West Africa), located on latitude 06^{o}27'N and longitude 03^{o}24'E. Lagos has the status of a megacity with population of 7.94million (2010) and population density of 7.938 inhabitants/km^{2}. The hottest months are February and March with mean temperatures of 29^{o}C – 30^{o}C. The table below gives trend in dry bulb temperature for the years 1993 to 2008. The tabulated months are those in which the mean maximum temperatures occurred.

Lagos has a warm humid climate with a dust laden atmosphere 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 emanates from the gleeful communities and boisterous drivers on Lagos roads. The humidity, which reaches over 85% in the mornings but rarely dropping below 65% in the afternoons, is a major cause of discomfort (Sangowawa et al, 2008).

Based on an outdoor condition of 34^{o}D3/28^{o}C WB, the relative humidity is 65% and the humidity ratio is 0.21kg/kg. The humidity level is above the ASHRAE upper humidity level of 0.012kg/kg. Using the ASHRAE PMV (predicted mean vote), the comfort band in a formal office setting, (clo = 1.0), is 23^{o}C ± 2^{o}C at 50%RH.

Table 1 – Mean maximum and mean minimum temperatures in Lagos (1993-2008)

YEAR	MONTH	Max Temp ^{0}C	Min Temp ^{0}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
2007	Feb	34	24
2008	Feb	34	23

Source – Nigeria Meteorogical Services, Oshodi, Nigeria

High humidity, as normal in Lagos, can lead to discomfort (Tanabe et al, 1987; Berglund et al, 1986). The problem of the dust laden atmosphere, the vehicular pollution and the ambient noise exacerbate the humidity issue. Consequently the common recourse is to the use of mechanical cooling and dehumidification. For naturally ventilated rooms, the calculated adaptive comfort temperature is 28^{o}C ± 2.5^{o}C. This is still lower than the air temperature on a hot afternoon. This means that occupants will feel either very warm or hot. Adaptive actions would have to be taken to achieve a sense of comfort.

A qualitative study of two groups of inhabitants of Lagos was carried out. The first group was affluent enough to work and live in airconditioned environments. The second group did not have airconditioned dwellings but some worked in airconditioned offices. The result was that all the people surveyed were of the opinion that air-conditioning was necessary for optimal thermal comfort. Almost all the women desired airconditioning as a means of keeping out the dust. That way the windows would not need to be opened particularly during the exceptionally dusty harmattan season.

When questioned about what temperature settings would be appropriate for thermal comfort, only the technical minded engineers could relate to air temperature figures. Most of the unitary type airconditioners installed in dwellings have fan settings of low-medium-high and temperature settings ranges of 1-3. For units with digital settings, the norm is to keep the temperature very low at 16^{o}C and then adjust the fan speeds to suit the desired space conditions.

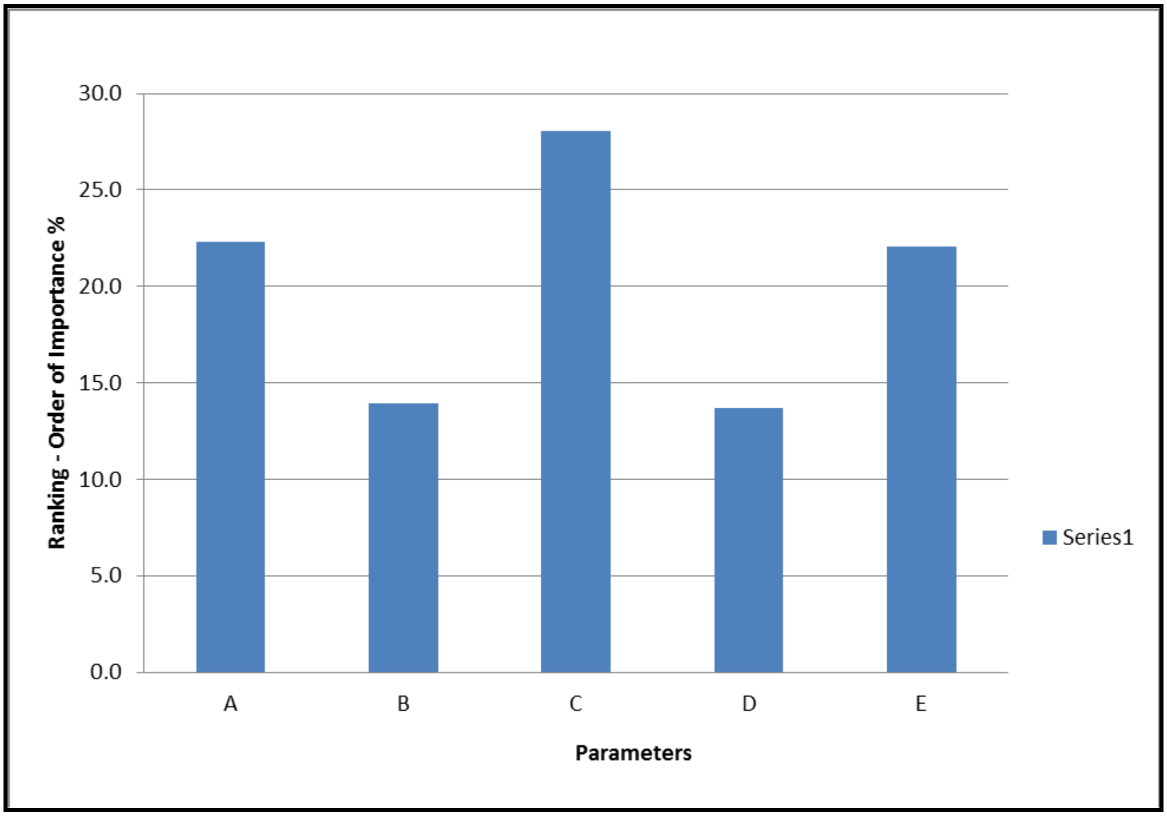
In a number of offices with central airconditioning, the occupants do not have easy access to the controls. In general offices the occupants are more tolerant of each other’s feelings of ‘too cold’ or ‘too warm’. Within the general office space where thermostats cannot be readily adjusted by an individual, the respondents admit they would adjust their clothing by either putting on or putting off a jacket. Some would take a hot or cold drink depending on how they feel. Some of the respondents indicated that they sometimes move around to warm themselves.

When asked about perceptions of space, some confirmed that a clustered office appears warm while a clean setting was satisfactory. A few were indifferent. The influence of colour on thermal comfort could not be ascertained. However, majority preferred light colours on the walls rather than dull shades. The ladies are of the opinion that flowers would help the mood.

All the respondents would love to have airconditioners at home. For those who had airconditioners, some mentioned the added advantage that the cool environment kept the mosquitoes inactive. “What is the use of thermal comfort when you are forever swatting mosquitoes?” This gave an interesting angle to the study. Thermal comfort would be meaningless if you have to contend with other nuisance problems. Could the ability to cope with a thermal discomfort depend on the severity of other issues?

To gauge this, 30 members of the study group were asked to rank a number of socio-economic issues in order of importance. The results are tabulated below. The adequacy of financial resources was uppermost in people’s mind at 28%. This was followed by the general state of the infrastructure and health issues with 22.3% and 22.0% respectively. Least important to the respondents were thermal comfort and the characteristics (décor, aesthetics) of the dwellings at 13.9% and 13.7% respectively. What this means is that most people are able to tolerate the least important issues without expressing a feeling of discomfort. Definitely there will be a threshold to the tolerance and this can be the object of further studies.

Figure 1 – Ranking of socio-economic issues in order of importance



A - General state of the infrastructure in the locality (roads, drains, water)

B - Thermal comfort (both at home and the office)

C - Financial resources (to meet crucial needs)

D - Building characteristics (aesthetics, decor, space)

E - Health as dependent on built environment (ventilation, damp, mosquitoes)

The findings also imply that thermal comfort cannot be measured solely by the PMV model. This agrees with the findings of Nikolopoulou et al, (2003) regarding thermal comfort for outdoor settings. Nicol et al (2002) also indicated as much in their presentation of adaptive cooling even though their emphasis was on the behaviour of the subjects rather than their psychological state: “if a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort.” Similar results were reported by James et al. (2012) in their study of the thermal comfort of school children in Ghana. Parts of the Ghanaian coast have similar climate with Lagos.

The concern about the infrastructure is expected. It had earlier been mentioned that the dusty atmosphere of Lagos is often times a nuisance. Regarding health, Darby et al. (2005) wrote: “The greater the importance of personal comfort and health to the household, the higher the consumption of airconditioning was likely to be.”

Those who do not have airconditioning at the moment were questioned about how they coped with the heat and humidity. The respondents adopt adaptive measures that include using an electric fan, hand fan, cold drinks, frequent showers, putting on minimal cloths, all in addition to opening the windows. They reported that situations can be unbearable when the windows have to be shut for one reason or the other. It is to be noted that Fountain et al. (1999) had found that there are no significant psychological or physiological differences in human response to exposure of between 60% to 90% relative humidity for the temperature range of 20ºC to 26ºC while sedentary.

When asked about the influence of colours, some members in the group without airconditioning indicated that they could not afford to have light colours because of the dust even though this would have been their preference. Indeed there is a lot of coping with this group. Generally the respondents did not link colours to thermal sensation but more to psychological comfort. Does comfort in one realm affect the feeling in another?

Almost all the respondents were comfortable during the rainy season when the temperatures would have dropped below 28^{o}C and the dust subsided. They would however still prefer an air-conditioned space. When questioned for a reason for this desire, the response was that temperatures swing up even in the rainy seasons. Albeit, they had a choice of switching the plants off if they felt too cold.

Low-Energy Thermal Comfort

A greater proportion of the low income residents of Lagos do not have access to air-conditioning in their homes. This is due to reasons of affordability. They commonly resort to the adaptive means of improving their thermal comfort.

Wherever possible, construction methods are such that would minimize the solar heat gains to the buildings while enhancing the natural ventilation of the spaces. This is achieved by appropriate orientation of the building and adequate insulation of the roofs. Indeed the houses from the early 1900s show significant considerations of sustainable designs. The walls are thick to aid thermal mass. There are wide balconies and overhangs to provide shading. There is also vegetation to enhance the cooling of the immediate outdoor environment

Figure 2 – Kings College Lagos (established 1909)

Another means of enhancing comfort is to provide naturalness by planting trees for shading as well as gardens to sooth the senses. Zen gardens have been introduced in some localities but, suffice to say, they were located in neighbourhoods where the inhabitants could readily afford air-conditioning.

Figure 3 – Residential development in suburb of Lagos

The global economic crisis has impacted the built environment in Lagos. Most Clients now accept the introduction of the cheaper air-conditioning systems that make use of the wall type or mini-split air conditioners. These are well suited for residential developments. Interestingly the efficiencies of these units have improved over the years to make them better comparative to the bigger and more complex units in terms of energy consumption.

Figure 4 – Residential apartments with wall unit airconditioners

74% of those who were surveyed further responded that airconditioning was not a luxury in Lagos. It is seen as a necessity. The challenge therefore would be to provide airconditioned environments that will optimize energy consumption and minimize the CO_2 emission that is presently attributed to the vagaries of climate change.

Gul et al, (2011) conducted a qualitative study of UK-based HVAC engineers to determine the approaches to design with particular respect to minimizing CO_2 emission (climate change). The results showed that the building form and characteristics were the major determinant followed closely by available budget. The comfort criteria came in third and CO_2 emission was fourth. Form and budget are still the major determinant of the type of airconditioning installed in the built environment.

The import of the above is that both the architects and the engineers would need to synergize to effect low-cost low-energy solutions for thermal comfort in buildings. The psychological impact of thermal comfort would also need to be exploited more. This will allow engineers to design airconditioning for spaces based on higher indoor temperatures without causing discomfort to the occupants. The typical design temperature for Lagos is 23^oC.

A comparative analysis was carried out to check the significance in energy savings by using higher indoor temperatures in airconditioning designs. A typical project in Lagos was chosen. The Client was an international bank organization with global policies of sustainable development. A low energy design was the goal. The façade is essentially curtain walling with double glazed low emissivity glass. The thermal properties of the façade and the roof were to conform to the UK Building Regulations 2010 - Part 2L. There are horizontal shading louvres at each floor to reduce the impact of incident solar heat gain. The internal lighting was based on energy efficient fittings and a lighting level of 400 lux was adopted (to be aided by task lights as required). The estimated air conditioning load at indoor temperatures of 23^0C, 24^0C and 25^0C are tabulated below.

Figure 5 – Sustainable development: Bank Office Building

Table 1: Comparison of estimated cooling loads for different indoor temperatures

INDOOR TEMP °C	ESTIMATED COOLING LOAD kW	LOAD/AREA RATIO W/m^2
23	542	143
24	522	138
25	504	133

For office developments in Lagos where sustainable factors have not been considered, the load/area ratio is in the range of 175 – 225W/m^2. As such, it can be said that the implementation of sustainable designs has been effective. An additional 38kW would be saved if the higher indoor temperature is adopted. There will be a savings in the operating expenses. In the UK, the projected energy savings that could be realized by varying the indoor temperature is about 10% (Nicol et al. 2002). The Lagos design was able to realize 7% as extensive insulation had been applied on the façade and roof.

However, sustainable development in Nigeria costs more than the convention means of construction by about 20 – 25%. Most Clients are unwilling to pay this extra-over-cost and would rather spend the additional money during the operation of the building. Unfortunately there is presently no legislation for sustainable development in Nigeria.

Conclusions

The impact of the global economic crisis has meant that professionals in the built environment would have to take a critical look at the concept of thermal comfort. There is need to give appropriate consideration to the psychological aspect of thermal comfort. This can be used to enhance the feeling of comfort in non-air-conditioned spaces and also contribute to energy savings in air conditioned spaces. It is still possible to provide a thermally conducive atmosphere in Lagos even at times like this. However there has to be a paradigm shift.

References

ASHRAE, **ASHRAE Handbook 2009** Fundamentals Chapter 9, American Society of Heating, Refrigerating and Air-conditioning Engineers, Atlanta

Berglund, L.G., (1995), **Comfort criteria: Humidity and standards**, Proceedings of Pan Pacific Symposium on Building and Urban Environmental Conditioning in Asia vol. 2, pp. 369-382, University of Nagoya, Japan, in ASHRAE, ASHRAE Handbook 2009 Fundamentals Chapter 9, American Society of Heating, Refrigerating and Air-conditioning Engineers, Atlanta

Berglund, L.G., and Cunningham, D.J. (1986), **Parameters of human discomfort in warm environments**, ASHRAE Transactions 92(2): pp. 732-746, in ASHRAE, ASHRAE Handbook 2009 Fundamentals Chapter 9, American Society of Heating, Refrigerating and Air-conditioning Engineers, Atlanta

Boeing Corp, (2002), **The psychology of comfort in airplane interior design**, Boeing media, http://www.boeing.com/commercial/news/feature/comfort.html. Accessed January 12, 2012.

Building Regulations 2010, **Approved Document L2A - Conservation of fuel and power, New buildings other than dwellings**, NBS, London

Darby, S., and White, R., (2005), **Thermal Comfort**, Environmental Change Institute, Univ of Oxford. http://www.eci.ox.ac.uk/research/energy/downloads/40house/background_doc_c.pdf. Accessed January 15, 2012

de Dear, R., Brager, R., and Cooper, D., (1997), **Developing and adaptive model of thermal comfort and preferences - Final Report**, ASHRAE RP-884

de Dear, R., Leow, K., and Ameen, A., (1991), **Thermal comfort in the humid tropics - Part 1**, ASHRAE Transactions 97(1):874-879

Fanger, P.O., (1972), **Thermal Comfort**, McGraw-Hill, New York

Fountain, M., Arens, E., Bauman, F.,Tengfang, X., and Oguru, M., (1999), **An Investigation of thermal comfort at High Humidities**, ASHRAE Transactions vol. 105, Part 2, 1999 ASHRAE RP-860

Gagge, A.P. (1937), **A new psychological variable associated with sensible and insensitive perspiration**, American Journal of Psychology 20(2):277-287 in ASHRAE, ASHRAE Handbook 2009 Fundamentals Chapter 9, American Society of Heating, Refrigerating and Air-conditioning Engineers, Atlanta

Gul, M., Menzies, G., and Banfill, P., (2011), **Incorporating climate change projections into building design: a qualitative study**, World Renewable Energy Congress 2011 Sweden. http://www.ep.liu.se/ecp/057/vol2/005/ecp57vol2_005.pdf. Accessed December 17, 2011.

Hardy, J.D., Stolwijk, J.A.J., and Gagge, A.P., (1971) **Man**, in Comparative physiology of thermoregulation, Chapter 5, Charles C. Thomas, Springfield, IL. In ASHRAE, ASHRAE Handbook 2009 Fundamentals Chapter 9, American Society of Heating, Refrigerating and Air-conditioning Engineers, Atlanta

Heerwagen, J.H. and Heerwagen, R., (1984), **Energy and psychology: Designing for a "state of mind"**, Journal of Architectural Education, Vol. 37, No.3/4, Energy (Spring-Summer, 1984), pp.34-37, Blackwell Publishing

Hensel, H. (1973), **Temperature reception and thermal comfort**, Archives des Sciences Physilogiques 27:A359-A370, in ASHRAE, ASHRAE Handbook 2009 Fundamentals Chapter 9, American Society of Heating, Refrigerating and Air-conditioning Engineers, Atlanta

Hoof, v J., Mazej M., and Henson J. L. M., (2010), **Thermal Comfort: research and practice**, Frontiers in Bioscience, 15(2), 765-788, http://www.bwk.tue.nl/bps/hensen/publications/10_fbs_hoof.pdf. Accessed January 10, 2012

James, A., and Christian, K., (2012), **An assessment of thermal comfort in a warm and humid school building at Accra, Ghana**, Pelagia Research Library, Advances in Applied Science Research, 2012, 3(1):535-547,

Nicol, J.F. and Humphreys, M.A., (2002), **Adaptive thermal comfort and sustainable thermal standards for buildings**, Energy and Buildings 34 (2002) pp. 563-572, Elsevier Science B.V.

Nikolopoulou, M., and Steemers, K., (2003), **Thermal comfort and psychological adaptation as a guide for designing urban spaces**, Energy and Buildings 35 (2003), pp. 95-101, Elsevier Science B.V.

Rohles Jnr, F.H. (2007), **Temperature and temperament - a psychologist looks at comfort,** ASHRAE Journal February 2007, pp.14-22

Sangowawa, T., Adebamowo, M.A., and Godwin, J., (2008), **Cooling, comfort and low energy design in warm humid climate: the case of Lagos**, Nigeria, Network for Comfort and Energy Use in Buildings - Windsor Conference 2008

Tanabe, S., Kimura, K., and Hara, T., (1987) **Thermal comfort requirements during the summer season in Japan**, ASHRAE Transactions 93(1): pp. 564-577

The Central Bank of Nigeria, 2011, **Economic Report 3rd Quarter 2011,** CBN website: www.cbn.gov.ng

The Telegragh Online Newspaper, 2011, **Household spending power suffers biggest drop in 34 years**, http://www.telegraph.co.uk/finance/personalfinance/8604540/Household-spending-power-suffers-biggest-drop-in-34-years.html. Accessed January 27, 2012

United Nations, Department of Economic and Social Welfare web site - **Challenges to sustainable development, 2009**. http://www.un.org/en/development/desa/financial-crisis/challenges.shtml. Accessed January 10, 2012

Vaitiligam, Robert, (2009), **Recession Britain - Findings from Economic and Social Research**, Economic and Social Research Unit, UK, www.esrcsocietytoday.ac.uk

World Bank (2012), **Global Economic Prospects: Uncertainties and vulnerabilities.** http://siteresources.worldbank.org/INTPROSPECTS/Resources/334934-1322593305595/8287139-1326374900917/ExecutiveSummary_GEPJan2012_Eng.pdf. Accessed January 27, 2012