

## A Review of Climate Change and the Architects' Perspective towards Achieving Thermal Comfort in Buildings in South – Eastern Nigeria

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### Abstract

The paper reviewed the trending topic of climate change. It x-rayed its causes, progression and effects on our environment, especially as it affects indoor thermal comfort in buildings in south eastern Nigeria. The paper agreed to facts from scholars on the issue that our globe has been going through a warming period, and that the action is most likely to continue. Climate change was concluded to be responsible for present environmental degradation in our societies, especially those arising from increase in temperature, ocean surge, desert encroachment acid rain and heat stroke to mention a few. These unholy occurrences have left sad memories in our minds and environments, and should be discouraged. The paper assessed the thermal effects on buildings especially in south eastern states of Nigeria, and called on architects and other professionals in the challenge and come up with architectural solutions that will ameliorate presently felt thermal discomfort in buildings and bring sustainable healing thermal healing in indoors of our buildings. The paper then enumerated architectural design and developmental guidelines that will lead to reduced in indoorheating, and attainment of acceptable thermal comfort status.

**Keywords:** *Architects perspective, Climate change, Global warning, Hot/ wet humid climate, Thermal comfort*

### **Background to the Study**

Our planet Earth has been described as the Goldilocks planet, because for people and other life on earth it is mostly not too hot and not too cold but just right (Anthes, 1992).

Climate refers to the representative or characteristic atmospheric conditions (what we call weather) at a place or places on Earth. Whereas climate refers to long periods, such as seasons, years, or decades, weather conditions refer to short periods of time, such as days or weeks. Because the climate of a particular location may depend on extreme or infrequent conditions, it is more than just the average temperature and precipitation. The simplest classification of climate is by latitude-tropical, subtropical, midlatitudinal (continental), subarctic (continental), and arctic-but several other categories are necessary, including humid continental, mediterranean, monsoon, desert and tropical wet-dry, among others. Both precipitation and temperature show tremendous variability on a global scale (Botkin and Keller, 1998).

On a regional scale, air masses that cross oceans and continents may have a profound influence on seasonal patterns of precipitation and temperature. On a local scale, climate conditions can also vary considerably and produce a local effect referred to as microclimate. Microclimate may vary even from one side of a small rock to another or from one side of a tree to another. Organisms often take advantage of these different conditions. Furthermore, urban areas produce a characteristic microclimate with important environmental consequences.

### **The Urban Microclimate**

The very presence of a city affects the local climate and as the city changes, so does its climate. Before now most very healthy environments have been made sick by air pollution. The effects of tall buildings on air flow lead to a conclusion of unhealthy environment. Although air quality in urban areas is in part a function of the amount of pollutants present or produced, it is affected also by the city's ability to ventilate and flush out pollutants. The amount of ventilation depends on several aspects of the urban microclimate (Botkin and Keller, 1998).

In furtherance to their contribution earlier, both inferred that cities are warmer than surrounding areas, and that observed increase in temperature in urban areas is approximately 1° to 2°C (2° - 4°F) in the winter and 0.5° to 1.0°C (0.9° - 1.8°F) in summer for midlatitude areas. The temperature increase results from the increased production of heat energy – the heat emitted from the burning of fossil fuels and other industrial, commercial and residential resources – and the decreased rate of heat loss because the dust in the urban air traps and reflects back into the city long – wave (infrared) radiation emitted from city surfaces. Concrete, asphalt, and roofs also tend to act as solar collectors and quickly emit heat into the air (Houghton, 1994).

Cities are in general less windy than nonurban areas. Air over cities tends to move more slowly than in surrounding areas because buildings and other structures obstruct its flow. Wind velocities are commonly reduced by 20% to 30% in urban areas, and calm days are 20% more frequent than in nearby rural area (Mohen et al; 1991).

Particulates in the atmosphere over a city are often at least 10 times more abundant than in surrounding areas. Although the particulates tend to reduce incoming solar radiation by up to 30% and thus cool the city, the effect of particulates is small in relation to the effect of processes that produce heat in the city (Mohen et al; 1991).

The combination of lingering air and abundance of particulates and other pollutants in the air produces the well – known urban dust dome and heat island effect. Particulates in the dust dome serve as seeds for the condensation of water vapor; thus urban areas experience 5% to 10% more precipitation and considerably more cloud cover and fog than do surrounding areas. The formation of fog is especially troublesome in the winter and may impede air traffic into and out of airports. If the pollution dome moves downwind, increased precipitation may be reported outside the urban area (Botkin and Keller, 1998).

### **Climatic Change and trend**

Another important aspect of climate is climatic change. The mean annual temperature of the Earth has swung up and down by several degrees Celsius over the past 2 million years. Times of high temperature reflect ice – free periods (interglacial periods) over much of the planet; times of low temperature reflect the glacial events. It is not yet clear whether our current warm climate marks the end of the ice ages or whether we are merely in an interglacial period with another glacial age due.

Global climate also changes over time scales shorter than that of glacial – interglacial periods. Climatic change over the last 1500 years reflects several warming and cooling trends that have greatly affected people. For example, during the major warming trend from 800 to 1200, the Vikings colonized Iceland, Greenland, and North America. When glaciers advanced during the cold period around 1400, the Viking settlements in North America and parts of Greenland were abandoned (IPCC, 1991).

Starting in approximately 1750 a warming trend became apparent, lasting until the 1940s, when temperatures began again to cool (IPCC, 1991). What is evident from the record of the last 100 years is that global mean annual temperature has increased by approximately 0.5° to 0.7°C (0.9° - 1.3°F). Furthermore, the decade from 1986 through 1995 has been the warmest in the 135 years that global temperatures have been monitored. This decade includes the seven warmest years of the twentieth century (OECD/ IEA, 1994, Titus et al; 1995)

There is considerable debate about whether we are entering a period of increased global warming or whether the recent trends are part of normal climatic cycles. Because of the complexities of climate and climatic change, we are unable to answer this question at present. A recent report from an international panel of climate experts concluded that, based upon the balance of scientific evidence, there is a discernible human influence on global climate. However, panel members could not unequivocally state that human – induced global warming is in fact occurring (IPCC 1991). However, serious consideration is being given to the possibility that global warming is in fact occurring as a result of increased emissions of gases that tend to trap heat in the atmosphere or that global cooling is occurring as a result of increased particulate emissions from burning coal that reflect incoming solar radiation back into space (IPCC 1991).

### **Global Warming: the Greenhouse Effect**

Global warming is defined as a natural or human – induced increased in the average global temperature of the atmosphere near Earth's surface. The temperature at or near the surface of Earth is determined by four main factors (Botkin and Keller 1998):

1. The amount of sunlight Earth receives,
2. The amount of sunlight Earth reflects,
3. Retention of heat by the atmosphere, and
4. Evaporation and condensation of water vapor.

The sunlight that reaches Earth warms both the atmosphere and the surface. Earth's atmospheric system then reradiates the heat as infrared radiation (Botkin and Keller 1998). Water vapor and several other gases, including carbon dioxide, methane, and CFCs, warm Earth's atmosphere because they absorb and reemit radiation. They trap some of the heat energy radiating from Earth's atmospheric system. The trapping or warming is somewhat analogous to a greenhouse, which also traps heat; thus the process has been called the greenhouse effects. Actually, the process of trapping heat in the atmosphere might better be called the atmospheric effect, because the dominant process responsible for heating the air in a greenhouse is quite different from that which heats the lower atmosphere.

Although some infrared radiation is trapped in a greenhouse, the dominant process responsible for warming the air is the restriction of cooling by air circulation (wind) because of the glass enclosure. Nevertheless, *greenhouse effect* has become the accepted term for the trapping of heating by the atmosphere. It is important to understand that the effect is in fact a natural phenomenon that has been occurring for millions of years on Earth as well as on other planets in our solar system. The majority of natural greenhouse warming is due to water in the atmosphere. On a global level, water vapor and small particles of water in the atmosphere produce about 85% and 12%, respectively, of our total greenhouse warming. We are not particularly worried about water vapor in the future because it is not significantly increasing in the atmosphere as a result of human – induced processes. The gases we are concerned with are those that result in part from *anthropogenic* processes, that is, those that result from human activities (IPCC 1991). These include carbon dioxide, CFCs, methane, nitrous oxides and ozone, all of which have increased significantly in the atmosphere in recent years. The CFCs are a group of inert, stable, human – made chemicals that are used as propellants in spray cans (deodorants, paints, etc.) and as the working fluid in appliances such as air conditioners and refrigerators.

Approximately 200 billion metric tons of carbon in the form of carbon dioxide enters and leaves Earth's atmosphere each year as a result of a number of biological and physical processes. Humans should be concerned about the anthropogenic greenhouse effect as it relates to:

1. The burning of fossil fuels, which adds about 5.4 billion metric ton of carbon each year to the atmosphere, and deforestation, which adds another 1.6 billion metric ton per year, increasing the concentration of atmospheric CO<sub>2</sub>; and
2. Human activities that emit other greenhouse gases, such as CFCs, ozone, methane and nitrous oxides.

### **Climate and Human Thermal Comfort**

Human beings keep their internal body constant at 37°C under different inner and outer conditions in order to stay healthy. This happens by keeping a balance between the heat produced and received by the body and the amount of heat loss by the body (Royle & Walsh, 2006; Stathopoulos, 2009). This is maintained by physiological processes. Increased production of heat is compensated by increasing heat loss through sweating, while a fall in body temperature leads to increased heat production through shivering. The excess heat produced within the body is normally eliminated through the physical processes of radiation, conduction and evaporation. These processes are usually influenced by the ambient and radiant temperatures, humidity of the air, wind speed and the degree of exposure to sunshine (Ayode, 2011; Akinyeye, 2000; Umoh, 2000; Evans 1976).

According to Ferguson (2002), low humidity encourages evaporation of perspiration from the human body which allows a rapid cooling of the skin. The converse is also true; increase in humidity decreases the evaporation of perspiration thereby inhibiting the cooling efficiency of sweating (Indraganti et al; 2012).

The evaporation process is further influenced by wind speed and exposure to sunshine. Ayode (2011), inferred that high wind speed facilitates constant replacement of air around the body and this accelerates the evaporation process. However, if the air is calm the air layer close to the body becomes saturated and little or no more evaporation goes on. According to Salmon (1999), this is further reduced by direct exposure to sunshine. The interaction of all these climate variables and such other physiological factors as metabolic rate, clothing, age and degree of acclimatization is said to be accountable for human thermal comfort (Indraganti et al; 2012; Ayode, 2011; Stathopoulos, 2009; Ogunsote, 1990 and Evans, 1980).

### **Thermal Indices**

Many attempts have been made by experts to develop thermal indices which combine some or all of these variables in one value to assess the level of human thermal comfort. Such indices include the Effective Temperature (ET), Corrected Effective Temperature (CET), Standard Effective Temperature (SET), the Resultant Temperature (RT), the Heat Stress Index (HSI), the Equivalent Warmth (EW), the Equatorial Comfort Index (ECI), the Predicted Four Hour Index (P4SR), the Operative Temperature (OT), the Index of Thermal Stress (ITS), the Bioclimatic Chart, the Mahoney Scale, the Evans Scale, the Predicted Mean Vote (PMV), the Predicted Percentage Dissatisfied (PPD). The most commonly used in the tropics are however, Bioclimatic Chart Scale. Some of these indices, like the Mahoney Scale shown in table 1, which compare predetermined comfort limits however, vary from country, culture to culture and from one climatic zone to another.

**Table 1: The Mahoney Scale of Comfort Limits**

Relative Humidity	Average monthly temperature					
	Over 20°C		15°C-20°C		Under 15°C	
	Day	Night	Day	Night	Day	Night
0-30%	26-24	17-25	23-32	15-23	21-30	14-21
30-50%	25-31	17-24	22-30	15-23	21-30	14-21
50-70%	23-29	17-23	21-28	15-21	19-26	14-19
70-100	22-27	17-21	20-25	18-24	18-24	14-18

Source: Ogunsote (1990)

South eastern Nigeria lies within warm and hot-humid climates which are characterized by high temperature and humidity. Wind speeds are generally low (Salmon, 1999). Designs for this area should therefore aim at reducing incident solar radiation and the transmission of such into living areas and also allow or enhance adequate air flow for ventilation and body cooling in order to improve thermal comfort (Oluigbo, 2004).

**Impacts of Global Warming on Built Environment in South – Eastern Nigeria**

Global warming has also been predicted to lead to changes in the local climate in most parts of the world (Holm, 2003). In Nigeria, there is increasing evidence of global warming with climatic variations and noticed weather changing conditions. Available metrological data indicate a temperature rise of 0.2-0.50C in some cities (Umoh 2000). A comparison of the day and night comfort limits in table 1 with monthly mean maximum and minimum temperature in table 2 supports these facts. Almost all the cities in South – Eastern Nigeria have experienced hot weather both in the day and in the night. Other climatic variables other than temperature have expressed appreciable variations. Table 3, for example, shows an increasing trend in humidity in South – Eastern Nigeria and rainforest areas of the country. Umoh (2000) also observed a general increase in the sunshine running from a minimum of 1300 hours in the Niger Deltato over 3200 hours in the extreme north-east. Abia State is within the Niger Delta zone.

**Table 2: Average Monthly Maximum and Minimum Temperature of the Selected Cities**

Month	Aba		Owerri		Enugu			Abakiliki	
	Max (°F)	Min (°F)							
Jan	92	70.4	61.5	50.6	52.5	54.0	90.6	66.7	
Feb	91.8	71.0	44.3	48.9	40.8	46.3	91.2	68.2	
Mar	88.6	71.6	40.8	46.3	41.3	48.1	92.4	68.4	
Apr	88.6	73.4	46.7	54.9	44.5	50.7	95.0	73.0	
May	86.7	74.2	51.1	50.6	48.8	49.2	88.6	68.7	
Jun	87.1	72.6	50.5	52.6	51.1	50.4	86.4	70.4	
Jul	83.7	70.8	52.3	54.6	50.2	51.2	82.4	70.5	
Aug	81.4	70.5	50.5	51.4	47.5	50.4	85.0	70.0	
Sep	82.8	70.5	52.1	52.3	48.6	51.0	87.0	70.4	
Oct	85.8	68.7	48.3	54.4	44.2	49.6	88.6	69.2	
Nov	87.2	72.4	45.8	40.1	58.1	53.4	88.4	65.8	
Dec	89.4	68.8	57.0	52.6	50.1	47.5	90.0	70.2	
Average	87	61.2	49.8	50.7	48.1	50.1	88.8	69.2	

Source: www.meoweather.com/history/Nigeria.

**Table 3: Average Weather Conditions of Selected Cities in South – Eastern Nigeria (2013-2016)**

City	2013		2014			2015			2016			
	T (°F)	RH (%)	WS (m/s)									
Aba	88	81	1.6	88	80	2.2	80	84	1.8	80	88	2.0
Owerri	79	94	2.2	78	78	2.1	78	90	1.7	78	92	2.1
Enugu	84	90	1.8	82	80	1.9	86	93	2.0	82	84	1.8
Abakiliki	80	94	2.0	85	82	2.3	91	95	2.0	88	78	2.0

**Note:**T= temperature (degree Fahrenheit): RH= Relative Humidity (%): WS=Wind

**Source:** www.meoweather.com/history/Nigeria

All these trends could induce significant increase in humidity and temperature, and may increase perspiration and discomfort (Ferguson-Hill, 2002; Ayode, 2011). The cooling potential of natural ventilation that has been a technique of choice for mitigating this effect in hot humid regions would fail with rising outdoor temperature which can trigger public health crises and health-related deaths (Wilby, 2009; Salmon, 1999). Peter and Adewale (2015) in a similar study in Southern Nigeria noted that a new meningococcal strain has just been discovered which was reported to be responsible for significant increase in cases and outbreaks of meningitis in African countries especially in Burkina Faso, Mali, Niger and Nigeria. They inferred also that severe perspiration causes heat stress and that if the indoor air quality is very low, that air purification function of ventilation would be impaired. This is supported in (Umoh, 2000). Poor air quality may cause respiratory infection, chronic obstruction, pulmonary disease, respiratory tract cancers, tuberculosis, cataracts and asthma (Lawanson 2008). The low structural cooling brought about by in-effective ventilation and intense radiation creates danger in structural integrity of building and may increase the incidence of building collapse. Among other effects of high humidity and high solar radiation, are color deterioration and dilapidation in buildings (Salmon, 1999; Umoh, 2000).

Reports by DIFID (2009) reveals that prediction have it that Nigeria is most likely to witness further temperature rise of 3.2°C and other weather extreme situation by 2050. That implies therefore that, building fabrics would retain more energy during the day, and that their rate of radiative cooling during the night would be low. Winds retain more solar energy, with less convective heat losses and evapotranspiration, thus yielding more energy for surface warming (Wilby, 2009; Eichebelger, et al, 2008; Roaf, et al, 2009). Heat stress and other heat-related illness are, thus, expected to increase in frequency and severity especially in the arid and littoral areas. Adequate adaption strategies that would minimize the impending catastrophes are therefore imperative. Peter and Adewale (2015) were right to note in a similar study that if architecture is understood as a responsive and problem-solving profession, then architects have a strong responsibility to this effect.

### **Architects Approach to Problems of Climate Change**

It is in order to conclude from the study that the urban centers in south - eastern Nigeria are getting warmer annually as predicted. Wind speed is also predicted to reduce, this implies that architectural products in South – Eastern Nigeria will experience increase in outdoor temperature and this will in turn reduce the cooling potential of natural ventilation. A situation that could be made worse by tall solid fence walls which is usually built very close to the buildings, mostly in urban areas and housing estates. Equally developers who import western building typologies and materials, which are environmentally disadvantaged are most likely to suffer severe discomfort in their buildings as most building materials and designs create unhealthy buildings, who's indoors are cells of unhappiness, and potential incubation of non-tropical diseases.

This paper agrees with the recommendation of Peter and Adewale (2015) who concluded that if the environmental goal of reducing greenhouse gas is to be achieved, and at same time build resilient cities and structures that can stand up to the imminent overheating, then the key to comfortable survival is architectural designs that reduces solar penetration into buildings and enhances air circulation within and between buildings. This could be achieved by following the design guidelines:

#### **Layout and Form**

Buildings should be arranged in a manner that will prevent them casting shadow on others. Streets should be aligned in parallel, or up to 30° to the prevailing wind direction to minimize the penetration of prevailing wind through the array of buildings in urban environments. As noted in Ogusote (1990), optimum ventilation could be achieved when distances between buildings are not less than six times its height. It is very necessary to observe all building regulations among which, all setbacks is obvious.

#### **1. Roof Design and Materials**

Roof is a building element that receives direct sunlight. Its design and construction therefore plays important role in the mitigation of heat stress. A highly reflective material with a wide overhang for protection against direct sunlight is recommended. A pitched roof of considerable slope is preferred as, this lowers incidence of global solar radiation (Melo, et al; 2004). Higher ceiling heights can also increase thermal climate of buildings, as this cause the hot air layers to be pushed away from the interior (Guarmaes, et al, 2013; Mofrad, 2013).

#### **2. Landscape**

Thermal discomfort can be accomplished through careful design of external areas. Hard paving's mitigations such as concrete, bitumen, stones, etc. have high heat capacity and thus dissipate much heat at night. Extensive and continuous stretch of parking lots should therefore be avoided. Mixing car parks with green areas facilitates and enhances thermal comfort. Vegetation, absorbs unwanted carbon dioxide, cleans the air, reduces the sun glare; absorbs solar radiation; and by transpiration, cools the air, and grasses help reduce overheating of air.

### **3. Shading Devices**

Projecting structures such as overheating cornices and vertical screens could be used as sun control measures, balconies, verandas, courtyards and other outdoor living areas should be encouraged as they shade building walls, openings and outdoor surfaces, and by so doing, keep the temperature of the outdoor air low, and enhances natural ventilation (Salmon, 1999). Light-colored curtains with high reflectance properties and ventian blinds are also very effective in controlling internal heat gain in buildings.

### **4. Material Specifications**

There is an established relationship between building materials and the thermal comfort desired in a space. All enclosure materials must therefore be carefully selected. Extensive use of fixed glass, in particular, should be avoided, as this triggers greenhouse effect. Greenhouse effects creates heat in buildings and causes discomfort in building interiors.

### **5. Fence-Wall Design**

Fence walls contribute much to heat gain in the buildings. (Alozie, 2014) in south – eastern Nigeria, the building regulation of 3 meters minimum set back from all adjoining properties should be enforced. Tall impermeable fence walls should be discouraged as they impede on wind speed and direction, thus creating regions of positive pressure on the wind ward sides and a suction pressure on the leeward sides (Oluigbo, 2004). Buildings located on the leeward side experience poor ventilation. Fence-walls should therefore be as low as possible, and visible fence –walls is preferred as it permits large quantity of air into the building it encloses.

### **Conclusion**

Architects and other professionals in the built environment with primary access to clients and developers should spare nothing in bringing to their awareness the need for thermal comfort in buildings and the many benefits, accompanying it, like energy preservation and improved health standard that awaits users of such buildings.

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