WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

The Impact of Climate Change on Buildings: The Case Study of Enugu Metropolis

[1]Amaifeobu, O.C, [2]Ekekezie, U.C & [3]Adewumi, A.C.

[1, 3]Building Department, Faculty of Environmental Sciences, Nnamdi Azikiwe University, Awka
[2]Building Department, Faculty of Environmental Sciences, Enugu State University of Science & Technology
Email: chukschy2012@gmail.com

ABSTRACT

climate change has brought a lot of discomfort to the built environment. This is worrisome and disheartening to the construction professionals and occupants of buildings. This study is a survey research that is anchored of three specific objectives: to assess the effects of climate change on buildings; to evaluate the perceptions of construction professionals on the causes of climate change in Enugu metropolis and to explore the key design parameters that will promote climate change resilient buildings in Enugu metropolis. A well-structured questionnaire distributed to 50 construction professionals in Enugu metropolis was used for collection of primary data. Data obtained were analyzed using weighted mean and relative important index (RII). The findings revealed that the major causes of climate change in Enugu metropolis are: urbanization, deforestation, solar variation, industrialization, cloud's contribution and emission of GHG; while the most outstanding effects of climate change on buildings include: blistering and bleaching of paints, disfiguring of walls, uplifting of roofs, unhygienic indoor & outdoor condition, and flooding. The study therefore recommends the followings as design parameters for climate change resilient buildings: design drainage based on landscape & topography of the area; use of building materials that are environmentally friendly and resilient to climate change hazards; design to counter high temperature: use of bright colour materials, raise roof & use of glass walls; adapting building orientation to skip direct solar impact; adopting bioclimatic design in our environment such as trees, open spaces etc. and anchoring of building elements against horizontal wind effects.

Keywords: Climate change, industrialization, resilient design parameter and urbanization.

1.1 Introduction

Nigeria's climate has been changing. This is clearly observed in: increases in temperature; variable rainfall; rise in sea level and flooding; drought and desertification; land degradation; more frequent extreme weather events; affected fresh water resources and loss of biodiversity (Elisha, 2017). The durations and intensities of rainfall have increased, producing large runoffs and flooding in many places in Nigeria (Ebele & Emodi, 2016). Rainfall variation is projected to continue to increase. Precipitation in southern areas is expected to rise and rising sea levels are expected to exacerbate flooding and submersion of coastal lands (Akande, 2017). Droughts have also become a constant in Nigeria, and are expected to continue in Northern Nigeria, arising from a decline in precipitation and rise in temperature (Amanchukwu, 2015). Lake Chad and other lakes in the country are drying up and at risk of disappearing (Dioha & Emodi, 2018). Temperature has risen significantly since the 1980s and Climate projections for the coming decades revealed a significant increase in temperature over all the ecological zones (Akande, 2017).

Climate change (CC) has been defined as the variation over time in weather elements, due to the factors of human activities or natural vulnerabilities (Odjubo, 2010). Climate change has become a global concern and its impact have continued to affect, threaten human life and to a large extent influenced the livelihood of most people across the globe (Cole, 2011). Expectedly, this development has attracted the attention of world political organization, like the United Nations Organization (UNO), hence has found its way at the top of global environmental agenda, especially in the twenty-first century.

The global concern over climate change has been highly acknowledged in literatures and increasingly, researchers have often argued that climate change has the capacity to impact all human activities in every region of the world (Bond, 2009) and they have therefore suggested proactive and sustained action to tackling its effects across countries.

Despite this unfortunate unfolding disaster, Nigeria and Enugu state in particular lack the capacity to contain the adverse consequences of climate change, which by implication makes them worst for it (Onyekuru & Marchant, 2011).

Generally, buildings have great impact and influences on the natural environment. Some researchers have noted that buildings contribute about 50% of the world's carbon emissions into the environment (Robert & Kummert, 2011). Other researchers also observed that about 90% of people spend about 90% of their daily time inside buildings (Robert & Kummert, 2011). It is therefore, necessary to minimise problems that occupants may face in terms of

comfort and climatic risks. Zubairu (2012) argues that in order to minimise the problems faced by occupants of buildings, a sustainable building design is required. While other similar literature suggests that there is an inter-relationship between climate change and buildings (Simoni, 2011).

Although buildings contribute to climate change, obviously buildings themselves are equally vulnerable to the impacts of climate change. According to UN Habitat report (2009) buildings are most vulnerable to climate change, because all the indicators of climate change such as flood, hurricane, bush fires and other adverse effects have huge consequences for the effective functionality of buildings. What this emphasized is an intertwined interface between buildings, the natural environment and climate change (William et al, 2012). Furthermore, it is the interface between a building's outdoor environment affected by climate change with its interior environment and the comfort required by its occupants that makes it significant (Zubairu, 2012).

This study is therefore an attempt to contribute to the future of buildings in Nigeria and in general terms to enhance designing of buildings that are resilient to climate change and environmentally sustainable.

1.2 Research aim and objectives

The aim of this research is to appraise the impact of climate change on buildings in Enugu metropolis. However, three specific objectives were focused on, which are:

i. to establish the extent to which buildings in Enugu metropolis have been affected by elements of climate change.

ii. to evaluate the perceptions of construction professionals on the causes of climate change in Enugu metropolis

iii. to explore and ascertain the key design parameters that will promote the design of climate change resilient buildings in Enugu metropolis

2.0 Conceptual framework

2.1 The concept of climate and climate change

Aremu (2019), defined climate as the sum total study of weather of a given place over a specific period of time. Climate is studied through its elements like temperature and radiation, atmospheric pressure, winds humidity and so on. Thus, climate pertains to an area and a long period of time of repeated observation of climatic elements in that area. It is important to note that climate of an area is fairly constant over a period of time and it is the constancy of the occurrence of a dominant weather element over an area for a long period of time that characterizes the climate of that area.

Climate change by definition is detected when a statistically significant variation in mean climate, or in its variability, persists for an extended period - typically 30 years. It is the statistics of change in weather over time that identifies climate change (Bhandari, 2018). The term climate change refers to changes that have occurred in the global climate since the 1900s and the ever increasing GHG emissions leading to the catastrophes associated to a changing climate (UK Climate Impact Programme (UKCIP), 2006). This has become a serious global environmental problem and is considered to be the most significant challenge facing global communities and therefore, making issues of climate change to be taken more seriously in recent times because of its devastating effects on the environment and its inhabitants (VijiyaVenkataRaman et al, 2012).

The rate at which the climate has been changing since 1970s is alarming based on published statistical data which shows an average global temperature rise of 0.2oC and a 2% rise in global precipitation (Heller & Zavalera, 2009). The impact of climate change is felt in all areas of physical, ecological and social wellbeing, therefore, could presents potential challenges to future livelihoods (Nath & Behera, 2011).

2.2 Major elements of climate

Balasubramanian, (2017), asserted that the long-term state of the atmosphere is a function of a variety of interacting elements. These elements include: solar radiation, air masses, pressure systems, ocean currents, and topography.

1. Solar radiation: is the radiation, or energy from the sun. It is also known as short-wave radiation. It first heats the earth's surface which in turn determines the temperature of the air above. The receipt of solar radiation drives evaporation, so long as there is water available. Heating of the air determines its stability, which affects cloud development and precipitation. Unequal heating of the Earth's surface creates pressure gradients that result in wind. The amount of solar radiation that reaches any spot on the earth's surface varies according to: geographic location, time of day, season, local landscape, and local weather. Solar radiation comes in many forms, such as visible light, radio waves, heat (infrared), x-rays, and ultraviolet rays.

2. Temperature: is a very important factor in determining the weather, because it influences other elements of the weather, such as precipitation, humidity, clouds and atmospheric pressure.

3. Air masses-wind and storms: An air mass is a large body of air with generally uniform temperature and humidity. Air masses control the characteristics of temperature, humidity, and stability. Winds is the horizontal movement of the atmosphere which can be felt only when it is in motion. It is the result of the horizontal differences in the air pressure. The speed of the wind is determined by the difference between the high and low pressure. The greater the difference the faster the wind speed and the closer the isobars, the stronger the winds.

4. Pressure systems: air pressure is the weight of air resting on the earth's surface. Air has specific weight which is called atmospheric pressure. It is defined as the force per unit area exerted against a surface by the weight of air above that surface in the Earth's atmosphere. Pressure systems have a direct impact on the precipitation. In general, places dominated by low pressure tend to be moist, while those dominated by high pressure are dry.

5. Ocean currents: this greatly affect the temperature and precipitation of a climate. Those climates bordering cold currents tend to be drier as the cold ocean water helps stabilize the air and inhibit cloud formation and precipitation. Air masses traveling over warm ocean currents promote instability and precipitation. Additionally, the warm ocean water keeps air temperatures somewhat warmer than locations just inland from the coast during the winter.

6. Topography: it affects climate in a variety of ways. The orientation of mountains to the prevailing wind affects precipitation. Air temperatures are affected by slope and orientation as slopes facing into the Sun will be warmer than those facing away. Temperature also decreases as one moves toward higher elevations.

7. Humidity: Atmospheric moisture is also an important element of the atmosphere which modifies the air temperature. It is the measurable amount of moisture in the air of the lower atmosphere. There are three types of humidity: absolute humidity, relative humidity, specific humidity.

8. Precipitation: it is the term given to moisture that falls from the air to the ground which include: snow, hail, sleet, drizzle, fog, mist and rain. It is simply any water form that falls to the earth from overhead cloud formations. As an element of weather, precipitation determines whether outdoor activities are suitable or if the water levels of lakes and rivers will rise. As an element of climate, precipitation is a long-term, predictable factor of a region's makeup.

9. Cloudiness: clouds are suspended water in the atmosphere. They are usually the most obvious feature of the sky. It gives us a clue about what is going on in our atmosphere and how the weather might change in the hours or even days to come. Clouds play multiple critical roles in the climate system. They efficiently reflect light to space and thus contribute to the cooling of the planet. Also, a small increase in cloud cover could, in principle, balance the heating resulting from greenhouse gases. Clouds are the base for precipitation.

10. Visibility: this is one of the most critical weather element. Obstructions to visibility include clouds, fog, smoke, haze, and precipitation. Visibility is often reduced by air pollution and high humidity. Fog and smoke can reduce visibility to near zero, making driving extremely dangerous. Heavy rain (such as from a thunderstorm) not only causes low visibility, but the inability to brake quickly due to hydroplaning.

2.3 Causes of climate change

Paehler, (2007) categorized the causes of climate change into two: natural and human activities.

2.3.1 Natural causes of climate change

The earth's climate is grossly influenced and changed through natural causes such as ocean current, volcanic eruptions, the earth's orbital changes and solar variations.

i) Ocean current: The oceans have been shown to be the major component of the climate system (Hoffman, et al., 2010). Ocean currents move vast amounts of heat across the world. Wind push horizontally against the sea surface and drive ocean current patterns. It has been shown that deep ocean circulation of cold water moves from the poles towards the equator and warm water from the equator back towards the poles. Without this movement the poles would be colder and the equator warmer (Brown, 2010). The oceans play an important role in determining the atmospheric concentration of CO_2. Changes in ocean circulation may affect the climate through the movement of CO_2 into or out of the atmosphere (Shanta Barley, 2010).

ii) Volcanic activities: Volcanic eruptions are known to throw out large volumes of Sulphur dioxide (SO_2), water vapour, dust and ash into the atmosphere. It is known that large volumes of gases and ash can influence climate patterns for years by increasing planetary reflectivity, causing atmospheric cooling. Tiny particles called aerosols are produced by volcanoes. Because these reflect solar energy back into space, they have a cooling effect on the earth's surface (Buja, & Teng, 2010).

iii) Earth's orbital changes: The earth makes one revolution around the sun once a year, tilted at an angle of 23.5º to the perpendicular plane of its orbital path. Changes in the tilt of the earth can lead to small but climatically important changes in the strength of the seasons, more tilt means warmer summers and colder winters; less tilt means cooler summers and milder winters. Slow changes in the earth's orbit lead to small but climatically important changes in strength of the seasons over tens of thousands of years. Climate feedbacks have been shown to amplify these small changes, thereby producing ice ages (Perkins, 2010).

iv) Solar variation: The sun is known to be the source of energy for the planet's climate system. Although the sun's energy output appears constant from an everyday point of view, small changes over an extended period of time can lead to climate changes. It has been speculated that a portion of the warming in the first half of the 20th Century was due to an increase in the output of solar energy. As the sun is the fundamental source of energy that is instrumental in our climate system, it would be reasonable to assume that changes in the sun's energy output would cause climate to change. But study by Paehler, (2007) have shown that if this were so it would be expected to see warmer temperatures in all layers of the atmosphere. On the contrary, the cooling was observed in the upper atmosphere, a warming at the surface and in the lower parts of the atmosphere. This was shown to be due to greenhouse gases capturing heat in the lower atmosphere. Furthermore, climate models that included solar irradiance changes could not reproduce the last century's observed temperature trend without including a rise in greenhouse gases suggesting that GHGs are the main cause of climate change (Paehler, 2007).

v) Cloud's contribution: Perkins (2010) reported that global satellite analysis supported by climate models have revealed that cloud cover accentuated warming because as earth's average temperature rises, clouds will accelerate global warming by trapping more heat. Dessler (2010) analyzed satellite data gathered between 2000 and 2010 to estimate the short-term variations in the amount of visible and infrared radiation emitted to space. He made an allowance by subtracting influences such as earth's surface reflectivity and the heat-trapping effect of atmospheric water vapour as well as how clouds affected the planet's radiation balance as a function of temperature over the decade. The result showed that clouds enhance warming by trapping on average, an extra 0.54 watts per square metre for every 10^0C rise in global average temperature. Dessler (2010) however, posited that uncertainty in the estimate indicates that clouds could actually exert a small cooling effect as temperature rises, although the slight negative feedback wouldn't be nearly enough to cancel out larger, well- constrained positive climatic feedbacks such as water vapour (Dessler, 2010). In the tropics, for example, Nigeria, the North East Trade wind brings cloudless atmosphere called harmattan with dry air and a cooling effect to the atmosphere. A model that can mimic this will have positive impact on climate change mitigation, provided it does not have negative feedback that could cause permanent drought.

2.3.2 Human influence on the climate system (Anthropogenic).

The result of a survey study conducted by the American Geographical Union (2009) saw 82% of Earth Scientist and 97.4% of Climate Scientist agreeing that human activities are actually responsible for climate change. The malfunctioning of one part of the climate system affects the overall performance of the system. A system should always be in equilibrium, the alteration of one part of the component affects the whole system. In this case, human beings due to our various activities tend to modify components of the climate system both deliberately and inadvertently (Sailor, 2006). The constant modification in the long run leads to climate change. It is only since the beginning of the Industrial Revolution in mid-18th century that the impact of human activities has begun to extend to a much larger scale, continental or even global. Human activities, in particular those involving the combustion of fossil fuels for industrial or domestic usage and biomass burning, produce greenhouse gases (GHGs) and aerosols which affect the composition of the atmosphere (Grimmond et al., 2007). The emission of chlorofluorocarbons (CFCs) and other chlorine and bromine compounds has not only an impact on the radiative forcing, but has also led to the depletion of the stratospheric ozone layer. Land use change, due to urbanization and human forestry and agricultural practices affects the physical and biological properties of the Earth's surface (Shahmohamadi 2010). Such effects change the radiative forcing and have a potential impact on regional and global climate.

Paehler, (2007) pointed out that some of the ways in which we humans change the climate system includes:

- ✓ deforestation,
- ✓ agriculture (through intensive farming- cattle and sheep produce large amount of methane when digesting their food, cultivation of rice produces methane and fertilizers used for planting releases nitrous oxide).
- ✓ Industrialization
- ✓ urbanization
- ✓ emission of greenhouse gases,
- ✓ loss of biodiversity - deforestation would cause loss of biodiversity and habits thereby altering the ecosystem, carbon sink problem (plants and trees counteracts climate change by capturing carbon dioxide).

To understand the climate of our planet earth and its variations and to understand and possibly predict the changes of the climate brought about by human activities, one cannot ignore any of these many factors and components that determine the climate. We must understand the climate system, the complicated system consisting of various components, including the dynamics and composition of the atmosphere, the ocean, the ice and snow cover, the land surface and its features. The many mutual interactions between them and the large variety of physical, chemical and biological processes taking place in and among these components.

2.4 Impact of climate change on buildings

Ebele & Emodi, 2016 and Akande et al, 2017 identified the impacts of climate change on building as follows: uplifting the roof, tilting or sliding of building due to horizontal wind pressure, overturning or rotating off the foundation, flooding, unhygienic indoor and out conditions, reduces the life span of building, building failure / collapse, blistering and bleaching of paints, disfiguring of walls, dust, smoke, and acidic rain.

2.5 Design parameters for climate change resilient / adaptation in building

The common words for solutions to climate change are adaptation and mitigation. According to the IPCC (1995) adaptation means: "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities." On the other hand, UNFCCC sees mitigation as: steps that countries are taking to address climate change and its adverse impacts. The two definitions are intertwined. But this paper primarily focuses on the adaptation strategies. Some of the adaptation measures and strategies identified for the Nigerian building industry include the following:

2.5.1 National Built Environment Adaptation Strategy

The Federal Ministry of Environment and its Works and Housing and Urban Development counterpart should partner with built environment professional bodies such as NIA, NIOB, NITP, NSE and development partners like the UN Habitat to chart an adaptation strategy that will address the copious climate related risks for the Nigerian built environment. This will go long way in promoting sustainable and affordable housing development in Nigeria. The professional bodies should design sustainable housing development codes such as zero carbon impacts as obtained in the UK and other countries.

2.5.2 Geographic Information System

There is need for professionals in the built environment to employ Geographic Information System or other tailor made data base that captures basic and systematic information about every region in Nigeria. Such information should be in integrated and used by designers in integrating climatic variables into the building industry. The proposed data bank would aid in raising awareness of professionals in the built environment.

2.5.3 Use of Appropriate Building Materials

Many of us are convinced beyond reasonable doubt that the building materials currently and commonly used by the Nigerian building industry have little proof for the vagaries of climate change. Now, in every wet season houses and other installations are being destroyed by the new patterns of early rains that come rather torrentially and heralded by wrathful and merciless storms. Floods also wreak havoc to many settlements. Based on these challenges it is high time for professionals and organisations like INTBAU to come up with appropriate building materials that are environment friendly, affordable and resilient to climate change hazards. For instance, we must not roof houses with dark colour that would absorb more heat or completely tile our houses and neighborhoods. We must use tiles that would absorb water to allow for better ground-atmosphere exchanges. Also adopts brighter colours (mainly cream and white). Invariably, the brighter colours would mean less absorption and retention of heat in addition to aesthetics.

2.5.4 Bio-Climatic Design

Design for climate change adaptation does not start at a single building; rather it integrates neighborhoods, and can be extended to towns, cities and even conurbations. In that respect, we can say bioclimatic design is most suitable and desirable adaptation mechanism to address the wide range of challenges in our cities. Bioclimatic design involves the green infrastructure in urban areas which includes open spaces, woodlands, street trees, fields, parks, community gardens, village greens, private gardens, and green or living roofs and walls. Bioclimatic design is anecdote for urban heat island (UHI). Bioclimatic designs aim at creating a conscientious balance between land use and natural resource development.

2.5.5 Design for High Temperature

With anticipated increase in temperature we need designs that appreciate this challenge through some of the following: raise roofs to reduce the direct impact of solar radiation; use of aerated clay blocks; use of more and larger windows for lightning; use of fiber materials; use bright coloured materials and use of glasses

2.5.6 Building Orientation for Thermal Comfort

Orientation of buildings to skip direct solar impact is perhaps one of the oldest adaptive measures against heat used by humans. Buildings are aligned in North/South direction in the northern hemisphere in order to avoid direct radiation of the rising or setting sun. The contemporary humans should also apply this old method in addressing the issue of rising temperatures.

2.5.7 Flood Risks Control

In managing risks of flooding in our settlements designers should use a comprehensive landscape drainage and topographic data of any place to be developed or transformed. This would greatly help in managing flood risks and management at design level. Decision over drainage system will always depend on the type of natural drainage and hydrological system of the locality. channeling water away from the building, sealing the outer walls, drainage,

2.5.8 Storm Risks Management

Managing seasonal violent wind storms is another albatross on the shoulders of designers. As the frequency of windstorm incidences increases in Nigeria it is important to suggest some adaptive strategies for this challenge. Firstly, knowing the wind directions and speed is inevitable, secondly, the materials to be used in construction is another. Thirdly designs should be made in way that safety of house and neighborhood will be prioritized. For instance, roofing types and installations that wind can destroy, transport and deposit elsewhere causing damage are all issues that need to be considered in assessing, managing and reducing storm risks. Such measure includes installing shutters on windows and doors against wind pressures.

3.0 Methodology

This study is a survey research which employed both primary and secondary data. Primary data were obtained through a well-structured questionnaire distributed to fifty (50) randomly selected construction professionals (mostly Architects, Builders and Structural Engineers) in Enugu metropolis. Secondary data were obtained from extensive literature review of published journal articles from the internet. The data were analyzed using simple percentage, weighted mean and relative important index (RII)

4.0 Data Analysis and Presentation

Although, 50 questionnaires were distributed, 48 were returned duly completed and therefore, used for data analysis.

4.1 The perception of construction professionals in Enugu metropolis on the major causes of climate change in the area.

Causes of climate change	1	2	3	4	5	Efx	Ef	Mean	RII	Rank
Natural causes										
Ocean current	5	7	4	8	24	183	48	3.81	0.76	7th
Earth's orbital change	33	4	11	0	0	74	48	1.95	0.39	8th
Solar variation	0	0	3	7	38	227	48	4.73	0.95	3rd
Cloud's contribution	0	1	4	9	34	220	48	4.58	0.92	5th
Volcanic activities	40	5	3	0	0	59	48	1.23	0.25	9th
Human activities										
Deforestation	0	0	2	5	41	231	48	4.81	0.96	2nd
Industrialization	0	0	3	9	36	225	48	4.69	0.94	4th
Urbanization	0	0	0	6	42	234	48	4.86	0.98	1st
Emission of GHG	0	0	5	11	32	219	48	4.56	0.91	6th

Source: Researcher's field survey, 2022

Table 4.1 above, revealed that six (6) of the assessed causes of climate change have RII > 0.8 and are therefore, rated very high. The implication is that; these are the outstanding causes of climate change as disclosed by construction professionals in Enugu metropolis. These causes ranked accordingly include: urbanization, deforestation, solar variation, industrialization, cloud's contribution and emission of GHG.

4.2 The impact of climate change on buildings

Impacts of climate change on buildings	1	2	3	4	5	Efx	Ef	Mean	RII	Rank
Uplifting of roof	0	0	3	5	40	229	48	4.78	0.95	3rd
Tilting of building	24	18	5	1	0	79	48	1.65	0.33	11th
Overturning of foundation	28	7	9	4	0	85	48	1.77	0.35	10th
Flooding	0	0	4	9	35	223	48	4.65	0.93	5th
Unhygienic indoors & outdoors condition	0	0	0	16	32	224	48	4.67	0.94	4th
Reduce building life span	1	3	3	14	27	207	48	4.31	0.86	7th
Building failure/collapse	3	8	5	3	29	191	48	3.98	0.80	9th
Blistering & bleaching of paints	0	0	0	3	45	237	48	4.94	0.99	1st
Disfiguring of walls	0	0	0	6	42	234	48	4.88	0.98	2nd
Dust & smoke contamination	0	1	10	17	20	200	48	4.17	0.83	8th

Acidic rain weakening building elements	0	2	5	8	33	216	48	4.50	0.90	6th

Source: Researcher's field survey, 2022

Table 4.2 above shows that out of the eleven effects of climate change on building assessed in this research, nine have RII > 0.8 and are therefore rated very high. This implies that; these effects are the most impactful effects of climate change on buildings in Enugu metropolis. However, the five most outstanding effects ranked accordingly include: blistering and bleaching of paints, disfiguring of walls, uplifting of roofs, unhygienic indoor & outdoor condition, and flooding.

4.3 Design parameters for climate change resilient / adaptation in buildings

Design Parameters For climate change resilient buildings	**1**	**2**	**3**	**4**	**5**	**Efx**	**Ef**	**Mean**	**RII**	**Rank**
Anchoring of building elements against wind effects	2	4	2	6	34	210	48	4.38	0.88	6th
Design drainage based on landscape & topography of the area	0	0	2	5	41	231	48	4.81	0.96	1st
Adapting building orientation to skip direct solar impact	0	2	1	9	36	223	48	4.65	0.93	4th
Design to counter high temperature: use of bright colour materials, & glass	0	1	2	8	37	225	48	4.69	0.94	3rd
Adopting bioclimatic design in our environment: trees, open spaces etc.	0	0	6	11	31	217	48	4.52	0.90	5th
Use of building materials that are environmentally friendly, affordable and resilient to climate change hazards	0	0	5	3	40	227	48	4.73	0.95	2nd
Designing building based on regional climatic variables as captured by GIS	31	6	10	1	0	77	48	1.60	0.32	7th
Designing of sustainable housing development code like zero carbon impact	39	1	8	0	0	65	48	1.35	0.27	8th

Source: Researcher's field survey, 2022

Table 4.3 above, disclosed that six of the design parameters for climate change resilient / adaptation in buildings assessed have RII > 0.8 and are rated very high. This indicates that; they are the most acceptable design parameters for climate change resilient by construction professionals in the study area. These parameters ranked accordingly include: design drainage based on landscape & topography of the area; use of building materials that are environmentally friendly, affordable and resilient to climate change hazards; design to counter high temperature: use of bright colour materials, & glass; adapting building orientation to skip direct solar impact; adopting bioclimatic design in our environment: trees, open spaces etc. and anchoring of building elements against wind effects.

4.4 Summary of Findings

This study has revealed that the major causes of climate change in Enugu metropolis are: urbanization, deforestation, solar variation, industrialization, cloud's contribution and emission of GHG. Also, the study disclosed that; the five most outstanding effects of climate change on buildings include: blistering and bleaching of paints, disfiguring of walls, uplifting of roofs, unhygienic indoor & outdoor condition, and flooding.

Above all, the following design parameters are declared acceptable to mitigate the impact of climate change on buildings: design drainage based on landscape & topography of the area; use of building materials that are environmentally friendly, affordable and resilient to climate change hazards; design to counter high temperature: use of bright colour materials, & glass; adapting building orientation to skip direct solar impact; adopting bioclimatic design in our environment such as trees, open spaces etc. and anchoring of building elements against wind effects.

5.0 Conclusion and Recommendations

Truly, climate change has brought a lot of discomfort to the built environment. This is worrisome to the construction professionals and occupants of buildings. This research has identified the major causes of climate change and the effects of climate change on buildings in Enugu metropolis. Based on the findings of this study, the researcher hereby recommends the followings as design parameters for climate change resilient buildings:

- ✓ design drainage based on landscape & topography of the area
- ✓ use of building materials that are environmentally friendly, affordable and resilient to climate change hazards
- ✓ design to counter high temperature: use of bright colour materials, & glass;
- ✓ adapting building orientation to skip direct solar impact
- ✓ adopting bioclimatic design in our environment such as trees, open spaces etc.
- ✓ anchoring of building elements against horizontal wind effects.

References

Akande, A. et al., (2017). Geospatial Analysis of Extreme Weather Events in Nigeria (1985–2015) Using Self-Organizing Maps. Advances in Meteorology. https://doi.org/10.1155/2017/8576150

Amanchukwu, R. N. et al. (2015). Climate change education in Nigeria: The role of curriculum review. Education, 5(3): 71-79. https://www.researchgate.net/profile/Nwachukwu_Prince_Ololube/publicat on/283081778_Climate_Change_Education_in_Nigeria_The_Role_of_ Curriculum_Review/links/56292c5508ae518e347c967b/Climate-Change Education-in-Nigeria The-Role-of-Curriculum-Review.pdf

Aremu, J.K (2019). Climate change or climate variability in Nigeria: An Overview. Abuja Journal of Geography and Environmental Management, 5, 90 - 98.

Bhandari, P.M. (2018): Climate Change Science: A Historical Outline: Advances in Agriculture and Environmental Science, February 2018.

Brown, A. 2010. Hydrology: Upstream impacts. Nature Climate Change. Doi: 10. 1038/nclimate 1016.

Dessler, A. E., 2010. A determination of the cloud feedback from climate variations over the past decade. Science 330: 1523–1527 (2010).

Dioha, M. O. and Emodi, N. V. (2018). Energy-climate dilemma in Nigeria: Options for the future. IAEE Energy Forum. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=10&ved=2ahUKEwihv4iA2-7kAhVoc98KHWNKDtw4Mh AWMDl6BAgQEAI&url=https%3A%2F%2Fwww.iaee.org%2Fen%2Fpublications%2Fnewsletterdlaspx%3Fid%3D465&usg= AOvVaw3qHlxFJnRFCXox9HBg4d-I

Ebele, N. E. and Emodi, N. V. (2016). Climate change and its impact in Nigerian economy. Journal of Scientific Research & Reports, 10(6), 1-13. http://www.journaljsrr.com/index.php/JSRR/article/view/21917/40737

Elisha, I. et al. (2017). Evidence of climate change and adaptation strategies among grain farmers in Sokoto State, Nigeria. IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT), 11(3), 1-7. http://www.iosrjournals.org/iosr_jestft/papers/vol11-issue%203/Version 2/A1103020107.pdf

Grimmond, C.S.B., W. Kuttler, S. Lindqvist, and M. Roth. (2007). Editorial: Urban climatology ICUC6. Int. J. Climatol. 27:1847–1848

Hoffman, R. N. et al. 2010. An estimate of increases in storm surge risk to property from sea level rise in the first half of the twenty-first century. Weather Clim. Soc. doi: 10.1175/2010WCAS1050.1.

Intergovernmental Panel on Climate Change (IPCC), 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the IPCC.

Perkins, S. 2010. Industry: Hard hits to ski resorts. Nature Climate Change. Doi 10. 1038/inclimate 1019.

Sailor, D. J. (2006). Mitigation of urban heat islands—Recent progress and future prospects. Paper presented at the Paper presented on American meteorological society 6th symposium on the urban environment and forum on managing our physical and natural resources.

Shanta Barley, 2010. Atmospheric science: Southeastern summer extremes. Nature Climate Change. Doi 10. 1038/inclimate 1012

Shahmohamadi, P., Che-Ani, A., Ramly, A., Maulud, K., & Mohd-Nor, M. (2010). Reducing urban heat island effects: A systematic review to achieve energy consumption balance. Paper presented at the Phys. Sci.

UN Habitat, Urbanization and Climate Change in Small Island Developing States. 2009, UN

Williams, K., et al., Suburban Neighbourhood Adaptation for a Changing Climate (SNACC) Final Report. 2012