CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Climate change is a major global phenomenon, which is evidenced by alterations in rainfall distribution, rising of glacier, ocean water expansion, drought, and increased temperature, (Intergovernmental Panel on Climate Change (IPCC), 2013). According to the World Meteorological Organization, climate change is determined based on average values of the weather variables over a period of at least 30 years (Anuforom, 2016).

Climate change is defined as a change in the state of the climate that can be identified by changes in the mean and /or the variability of its properties, which persists for an extended period typically decades or longer (IPCC, 2007). They further stated that the time taken to ascertain these changes varies as well as the level of deviation from the normal. Also, the impacts it has on the ecology.

Buildings are constructed to keep people away from the harmful effects of climate and weather. The effects of changes in climate usually make the internal environment uncomfortable and harsh. The changes in the climate parameters include: increase in temperature, strong wind and precipitation. As the climate changes there is a danger that current building designs will not be suitable for the new climate. However, it is likely that these effects would have to be rapid and severe to require substantial modification of existing buildings (Camilleri, 2000).

Climate change has different degrees of impact on the building systems. It affects the energy demands of the system in several ways. Climate change determines the energy demand of a building (Jenkins, Sandhya, Patidar and Simpson, 2015). Secular variations in climate occurring over a period of 100 to 150 years may not qualify as a climate change if conditions will quickly reverse later, but a change in climate usually takes place over a long period of time of at least 150 years with clear and permanent impacts on the ecosystem (Ayoade, 2003).

The possibility that the climate could be changing was first identified as far back as the 1960s, and the battle against climate change, and its main contributory gas, carbon dioxide (CO_2), has continued till now (IPCC, 2007). IPCC (2007) went further to reveal that the physical measurements of global CO_2 emissions have been taken since the 1950s. The Mauna Loa atmospheric CO_2 measurements constitute the longest continuous record of atmospheric CO_2 concentrations available in the world. The clear upland atmosphere of the Mauna Loa volcano on the Pacific Island of Hawaii is one of the most favorable locations on the planet for measuring undisturbed air because possible local influences of vegetation or human activities on atmospheric CO_2 concentrations are minimal and any influences from volcanic vents may be excluded from the records (IPCC, 2007).

The impact of climate change includes: drought, extreme heat waves, storms, tornadoes, floods, loss of life and properties and unusual weather phenomenon are all attributed to climate change and global warming. Due to the rate of climate change, new infrastructure will have to be able to cope with a large range of changing climate conditions, which will make design more difficult and construction more expensive (Hallegatte, 2009).

Nigeria, being a part of the global community is not, therefore, immune to the impacts of climate change. The climate condition of Nigeria is tropical, which basically is influenced by two winds; South-West wet monsoon which blows across the Atlantic ocean and brings with it rainfall and the North-East wind which blows across Sahara desert and brings along; dust, dry season and harmattan (Okereke, 2003).The increasing frequency and intensity of these extreme weather events, and the associated natural disasters, including negative impacts on building design, building materials and the cost of construction and maintenance, are a challenge to mankind.

Enugu Metropolis covers three local government areas; Enugu South LGA, Enugu North LGA, Enugu East LGA and nine principal districts; some of which are; Trans-Ekulu, Uwani, Coal Camp (Ogbete), Achara Layout, New Haven, Ogui etc (Ezenwaji, Nzoiwu and Eduputa, 2016), being in tropics has experienced the impact of climate change heavily. Some of the experiences are flooding, wind storm, erosion, and excessive heat due to increase in temperature among others. Flooding which results after heavy rainfall causes damages at different degrees and in some cases results in building collapse, loss of lives and properties. Most of these affected areas are deserted by the occupants because of imminent consequences of the effects of climate change (Enugu Capital Territory Development Agency (ECTDA, 2013). The sight usually is unpleasant and activities in such area are also disrupted due to the risk posed on human life. The issues of climate change constitute a major threat to socio-economic development programs in every country.

The industrial revolution and increase in human activities also have resulted in the emission and accumulation of carbon dioxide, nitrous oxide, methane and other greenhouse gases into the atmosphere. These gases allow solar radiation to penetrate the atmosphere and heat up the earth surface, but prevents the escape of the long wave (thermal) radiation back into space (Anuforom,2016). This is known as greenhouse gas effect, and these gases are known as the greenhouse gases (GHGs). The continuous trapping of excess thermal energy within the atmosphere has resulted in global warming and in turn climate change.

However, concern about the environment and the future of our planet has become the focal point of everyday conversation, political debate and media coverage all over the world (Glavinich, 2008). Extreme weather and climatic events have constituted serious threat to global economic growth over the past few years, especially to the socio-economy of developing nations. In Nigeria, severe floods, windstorms, heat waves and several other extreme weather and climate events have impacted negatively on its socio-economy and many people have been affected physically and psychologically (Nigerian Meteorological Agency (NiMet), 2014).

Hence, the (NiMet) is taking far reaching steps in contributing to the mitigation of these harsh weather impacts on the ordinary people, and lending support to the sustainable development of the country. Sustainable development cannot be achieved without having safe and affordable homes which through the centuries have been important aspects of the socio-economic development of humans (Windapo & Rotimi, 2012).

Construction industry is one of the most significant industries that contribute toward socio-economic growth especially to developing countries (Hussin,Rahman & Memon, 2013). In many developing countries, there is also a substantial need for shelter and basic services. Effective policies in those countries can lead to buildings, and wider settlements, that are climate resilient and use energy very efficiently, thus curbing the rise in GHG emissions. Opportunities for major energy savings also exist in the often wasteful and inefficient buildings of developed countries and emerging economies (Patrick, 2014).

The case is not different in the Africa’s urban population which is projected to triple by 2050, increasing by 0.8 billion though many of the continent’s evolving cities are unplanned, with informal settlements of inadequate housing. One of the constraints to understanding the present and predicting the future climate variability is lack of sufficiently dependable observational climate data in Africa (Osman-Elasha, 2007). A major issue also is the problems of low adaptive capacity in Africa which basically is its low level expertise in the climate science. Cities and towns are highly vulnerable to climate change impacts, typically lacking provisions to cut flood risks or manage floods when they arise. Climate change itself could affect Africa's rural and urban human settlements, being a determinant of the scale and type of rural-urban migration.

The continent's urgent adaptation needs stem from its sensitivity and vulnerability to climate change, coupled with poor adaptive capacity. Yet adaptation strategies can generate significant development co-benefits, boosting the chances of their adoption. Softer measures, such as building codes and zone planning, are being implemented. Indeed these consolidate hard and infrastructural climate proofing.

Nevertheless, buildings though affected by climate change, their operation contributes to GHG emissions and contribute significantly to climate change. The knowledge of the relationship between climate change and climate variability with all its parameters is a prerequisite to successful analysis of its impact on building construction and possible design of future resilient building to contain anticipated climate change and its impact. Building construction plays an important role in the sustainability development because it uses the earth's resources to raise the buildings where people live, work and play (Glavinich, 2008). These resources once tampered, would deplete and in some cases come to extinction, therefore the research analyses the changes in climate that leads to erosion, flooding, draught and other effect as they affect building design, building materials, construction cost, building energy use and maintenance cost.

1.2 Statement of the Research Problem

The effect of climate change is felt globally, however, Enugu state has experienced a lot of variations in climate. These include; increase in temperature (turning the city to a heat island), strong winds (that sometimes blow off roof tops), heavy rainfall, high sunshine intensity. The impact of climate change in the five decades includes building collapse, erosion, loss of land which could have been used for farming, construction or for industrialization. Notably, in 2017, third week of July after a heavy rainfall different locations experienced varying degrees of impact. The rainfall was unusual, it was prolonged, accompanied by heavy floods and strong winds. Houses around One Day area of Enugu South LGA were affected drastically, two building collapse were recorded. Three lives were lost, there were obstructions of movement both for the pedestrian and the vehicles. That was quite devastating; and such occurrences were also noticed in Emene, and Akpaka. This happens every year at the peak months of rainfall (July-August). The flood depth in some areas were as much as three meters (3m) and there were other incidences recorded by ECTDA and NEMA. So far, much has been written on climate change in Enugu State, this includes the study of "Urban Heat Island Research of Enugu Urban" (Eneta, 2005). But no time series or trend analysis has been carried out to determine the changes in the climate parameters and their effects on building designs, building cost, maintenance cost, building materials and energy need.

The varying changes in the climate parameters result in continuous changes in the design of buildings for the last five decades in a bid to combat these effects of climate change. This is to say that building designs have shifted over the decades. For example, considering the types of roofing materials used in the 1990s, which were corrugated roofing sheet (zinc), but was noted for poor thermal regulation making the internal environment uncomfortable and also causing an increase in the use of energy either to keep the internal enclosure warm or cool. The corrugated roofing sheet (zinc) was replaced by long aluminum roofing sheet. This was over taken by stone tiles. The stone tile is coated with natural stone that has better resistance to heat of sun preferred to ordinary galvanized steel roofing sheets.

Roofing pattern has also changed from flat roofing pattern to high pitched roofing pattern which consumes more materials. Invariably, this increases costs both on materials and labour. In addition, the increase in temperature has resulted in the use of more energy. Again, energy employed in production and operations is still on the increase. Building materials, considering cement as an instance has continually increased in price, rising from about #1300 in 2014 to #2600 in 2016. Both the production of cement, transportation and use have negative impacts on buildings. They also, emit more carbon dioxide into the atmosphere. The problem remains that in as much as design, cost of production, maintenance and energy use are on the increase. It is very clear that all these are happening because the climate continues to change. Variations like excessive rainfall leads to high surface run off causing flooding. A typical example of this is 2012 flooding which destroyed buildings, lives, land and properties (National Emergency Management Agency (NEMA), 2013).

In view of the above, a critical analysis of literature shows some serious gaps which constitute the core of this work. First, none of the works did an assessment of the impact of climate change on building design and cost in Nigeria, particularly Enugu State. Again, none of the works did a time series or trend analysis of the rate of change of climate variables with respect to building design for the past three decades in the study area.

Moreover none of the research works established whether or not the change in building materials is as a result of climate change or normal technological advancement. There were works reviewed under building energy needs variation like the work of Christenson, Manz and Gyalistras (2006), who investigated the impact of climate warming on Swiss building energy demand by means of the degree-days method, but none was done within the entire South Eastern Nigeria.

1.3 Research Aim and Objectives

The aim of this study is to appraise the effects of Building changes to climate variability in Enugu Urban Area with a view to develop a model to predict its future impacts in the study area.

To achieve this aim, the following objectives were pursued: to;

1. examine variation in climate parameters for five decades (from 1970-2017) within the study area.
2. determine the contribution of climate to change in building design (from 1970-2017) in the study area.
3. determine effects of climate change on the cost of construction and maintenance of buildings across the assessment time.
4. examine the perceptions of the respondents on the impacts of climate change on construction materials used.
5. examine the perceptions of the respondents on the impact of climate change on building energy need across the assessment period.
6. develop a model for predicting the effects of climate variability on building design, building materials, energy use, maintenance and construction cost.

1.4 Research Questions

This study to provided answers to the following questions:

1. Are there variations in climate parameters in the last five decades?
2. Does climate change have any contribution to building designs over the past five decades?
3. What are the effects of climate change on construction and maintenance cost over the study period?
4. Does climate change have impact on construction materials used?
5. What are the responses on the impacts of climate change on building energy need?
6. Is there a relationship between climate variables and building design, maintenance cost, building materials, energy use and construction cost?

1.5 Research Hypotheses

The research tested the following hypotheses:

1. H_o: there is no significant variation in climate parameters between 1970-2017
2. H_o: the perceptions of the respondents on the effects of climate variability on building designs are not significant.
3. H_o: the perceptions of the respondents on effects of climate variability on cost of building construction and maintenance are not significant.
4. H_o:the perceptions of the respondents on impacts of climate variability on energy need in buildings are not significant.
5. H_o: the perceptions of the respondents on impact of climate change on energy needs are not significant.

1.6 Scope and Delimitation

This research work concentrates on the analysis of the impact of climate change on buildings in the last five decades, (1970-2017). The analysis put into consideration the impacts of climate change on building design, building energy use, building materials, construction cost and maintenance, mitigation and adaptation. The research is to be carried out in Enugu urban area and focused on selected households and data was sourced from some registered professionals (which includes: Builders, Quantity Surveyors, Architects and Civil Engineers) in the study area in other to get the required data for analysis. Survey method was used to source part of the data, while data on climatic variables for the five decades (1970–2017) were sourced from NIMET.

1.7 Significance of the Study

The research predicts future climate change and guides development of adaptation and mitigation measures to ensure sustainable buildings under increasing climate variability and change. The professionals in the building industry need the knowledge to develop alternative options to increase their resilience buildings and cope with impacts of climate variability and change. This knowledge will also be useful to all stakeholders in the built environment to prioritize development interventions in Enugu State. This study contributes to an understanding of how buildings are impacted by climate change variables like temperature, rainfall, sunlight , perceived floods and droughts and how building can respond through adaptation and mitigation measures. It also looked into constraints to adaptation and mitigation, and required interventions.

The outcome of this research contributes to international, regional and national policies concerned with resilience building and sustainable development by providing knowledge that can enhance adaptation and mitigation measures. The study also contributes to the provisions of the United Nations Framework on Climate Change and its Kyoto Protocol as it advanced knowledge that can enhance mitigation measures, since no particular attention has been given to the building sector.

1.8 Limitations of Study

The research has the following limitation:

1. This research ought to have been done to cover the whole south eastern states with similar climatic conditions so as to give more accurate adjudications but for the cost implication and the time allowed; it was limited to Enugu Metropolis.
2. The research would have taken a wider scope in the area of time covered say like ten decade and even beyond to establish a more concrete trend of climate change but for the available data on climate variables and financial constrain, it was limited to five decades.
3. The research ought to have investigated all the building owners who were involved in the construction of their buildings within the time limit under review, but for want of time,

accessibility and cost, a random sample of the house owners was taken from the available number of households.

1.9 Definition of related Terms

1.9.1 Mitigation

Mitigation involves the use of advanced techniques for our buildings like the reflective materials, insulating materials, some cooling techniques, all this decreases the ambient temperature and improve indoor climatic condition and comfort (Farrou, Kolokotroni and Santamouris, 2010). Mitigation according to UNFCCC (2009) is aimed at reducing emissions to minimize global warming or avoiding the unmanageable. According to Rowan (2008) Mitigation refers to policy responses that attempt to cut down on greenhouse gas emissions or to sequester carbon and thus prevent it from entering the atmosphere. He further stated that Mitigation has historically been the policy of choice, and remains the most widely researched and implemented policy option. Mitigation is a response to a global commons problem, meaning the idea that a ton of carbon dioxide emitted anywhere in the world will produce the same polluting effect. He also opted that when studying mitigation it is advisable to focus on the entire globe, rather than concentrate on different localities.

1.9.2 Adaptation

A major challenge to the built environment is being able to predict with confidence the extent of vulnerability of the existing buildings to the effects of climate change (Snow and Prasad, 2011). An Architect must recognize that the nature of weather event does not remain same throughout the life-cycle of a building therefore should design for climate change adaptation. Adaptation is managing the unavoidable (GTZ/PIK 2009). It is crystal clear that no amount of mitigation will prevent the already existing devastating impacts of climate change, therefore the building sector must necessarily design to adapt (Ward and Wilson 2009).

According to Rowan (2008) in his thesis opined that adaptation is a policy that attempts to capitalize upon climate change impacts, rather than seeking to avoid those impacts all together. He also noted, as the likelihood that we are already facing climate has permeated the public consciousness, scientists and policy-makers have begun paying more attention to the possibility of adaptation.

UNFCCC (2007), in their report on impacts, vulnerabilities and adaptation defined adaptation as a process through which societies make themselves better able to cope with an uncertain future. Adapting to climate change entails taking the right measures to reduce the negative effects of climate change (or exploit the positive ones) by making the appropriate adjustments and changes.

They also opined that there are many opportunities to adapt, these range from technological options such as increased sea defenses or flood-proof houses on stilts, to behavior change at the individual level, such as reducing water use in times of drought and using insecticide-sprayed mosquito nets. Other strategies include early warning systems for extreme events, better water management, and improved risk management, various insurance options and biodiversity conservation.

Gaudioso (2008), in his research on 'Project act, adapting to climate change in time'' defined adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation" (IPCC TAR, 2007).

He also highlighted the definition by UNFCCC as "Practical steps to protect countries and communities from the likely disruption and damage that will result from effects of climate change. For example, flood walls should be built and in numerous cases it is probably advisable to move human settlements out of flood plains and other low lying area" (UNFCCC).

Adaptation - Is a process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed, and implemented. (UNDP, 2005)

In evolutionary biology, a textbook definition of adaptation refers to genetic or phenotypic changes that increase the fitness of a population or organism in a given environment.

Adaptation is also actions taken to reduce vulnerability to actual or expected changes in climate. It is an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (IPCC, TAR, 2001).

According to Smith et al (2010), adaptation is defined as, "adjustments to enhance the viability of social and economic activities and to reduce their vulnerability to climate, including its current variability and extreme events as well as longer term climate change."

1.9.3 Resilience

IPCC, TAR (2001) defined resilience as the capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. Building from the point of completion has a lot of loads to bear, live/imposed and dead loads, as such should be construction bearing this enormous responsibility in mind. The UKCIP (2003), defined resilience as the ability of a system to recover from the effect of an extreme load that may have caused harm. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures (UN/ISDR, 2004). It was also defined by UNDP, 2005 as a tendency to maintain integrity when subject to disturbance. Klein *et. al*. (2004) viewed resilience in two different ways and includes:

1. The amount of disturbance a system can absorb and still remain within the same state or domain of attraction;
2. The degree to which the system is capable of self-organization.

Tompkins *et al.* (2005), furthermore, explained resilience in three forms; conditions that enable social or ecological systems to bounce back after a shock, ability to self-organize, ability to buffer disturbance and capacity for adapting. Looking at the different definitions of resilience provided by the IPCC, UNDP and UN/ISDR on the one hand and the UKCIP on the other. The first institutions define resilience as the capacity of a system to tolerate disturbance without changing state; the UKCIP defines resilience as the ability to recover from the effect. These interpretations are different because in the first case resilience implies the ability not to sustain damage while in the latter interpretation resilience implies that the damage can occur and the system will be able to recover from it. According to Levina and Tirpak (2006), resilience is defined as the amount of change a system can undergo without changing state.

According to Füssel (2007), resilience can be defined as the ability of a system [human or natural] to resist, absorb and recover from the effects of hazards in a timely and efficient manner, preserving or restoring its essential basic structures, functions and identity. Resilience is a familiar concept in the context of Disaster Risk Reduction (DRR), and is increasingly being discussed in the realm of adaptation. A resilient community is well-placed to manage hazards, to minimize their effects and/or to recover quickly from any negative impacts, resulting in a similar or improved state as compared to before the hazard occurred. There are strong linkages between resilience and adaptive capacity; consequently, resilience also varies greatly for different groups within a community.

For the benefit of this research work, the researcher wishes to adopt the first interpretation which more or less points to mitigation rather than adaptation. That is in any case, the building structure is raised in such a way that it is protected and ready to manage any disruption from climate change without damage or failure rather than having measures to recover from the impact of climate change. The importance of this distinction is in the application of the term 'resilience' and attempts to measure it or measure approaches that increase resilience. The question about resilience is; are we talking about adaptation that increases the system's resilience in a sense that no damage or very insignificant damage can occur? Or are we talking about adaptation that increases our ability to recover from the damage?

1.9.4 Vulnerability

The vulnerability of the person to a climate risk is influenced by the design and fabric of the buildings they occupy, and their habits, age, health and wealth. People in traditional buildings often have well-understood capabilities of adapting their buildings and seasonal and diurnal lifestyles to extend the range of climatic conditions they can occupy safely and comfortably (Roaf, Crichton and Nicol, 2009). They further stated that those who live in settlements in already exposed locations such as hot deserts, in ' modern ' houses with thin walls and roofs, large windows, dependent on air conditioning, they are either infinitely more vulnerable to changes in climate, or less so, than those in traditional, thick-walled houses with shading and deep basements.

The ability of the modern house dweller to cope with extreme heat is dependent on their ability to pay for the energy to run coolers and the availability of electricity to run them. In the traditional house the ability to adapt the house lies with the homeowner, who is not at the mercy of the local grid and economy, utility prices, their own wealth and the global availability of oil. The young and the old, the weak and the sick are also more vulnerable to climate extremes (Roaf,*et al* 2009).

The importance of biophysical vulnerability is acknowledged as well. Many poor people are directly dependent on ecosystems for their livelihoods. Indeed, biodiversity is the foundation and mainstay of agriculture, forests and fisheries. Natural forests, freshwater and marine ecosystems maintain a wide range of ecosystem goods and services, including the provisioning and regulation of water flows and quality, timber and fisheries. The "poorest of the poor" are, often, especially dependent on these goods and services. For these groups, biophysical vulnerability means human and/or livelihood vulnerability

We see adaptation as a process focused on reducing vulnerability, which usually involves building adaptive capacity, particularly of the most vulnerable people. In some cases, it also involves reducing exposure or sensitivity to climate change impacts. In fact, adaptation is more than reducing vulnerability; it is about making sure that development initiatives don't inadvertently increase vulnerability.

Since reducing vulnerability is the foundation of adaptation, it calls for a detailed understanding of who is vulnerable and why. This involves both analysis of current exposure to climate shocks and stresses, and model-based analysis of future climate impacts. With this information, appropriate adaptation strategies can be designed and implemented. Monitoring and evaluating the effectiveness of activities and outputs, as well as sharing knowledge and lessons learnt, are also critical components of the adaptation process.

1.9.5 Impacts

Levina and Tirpak (2006), on their discussion on the consequences of climate change on natural and human systems, depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts (IPCC TAR, 2001)

1. Potential Impacts--All impacts that may occur given a projected change in climate, without considering adaptation.
2. Residual Impacts--The impacts of climate change that would occur after adaptation.
3. Aggregate Impacts- Total impacts summed up across sectors and/or regions. The aggregation of impacts requires knowledge of (or assumptions about) the relative importance of impacts in different sectors and regions. Measures of aggregate impacts include, for example, the total number of people affected, change in net primary productivity, number of systems undergoing change, or total economic costs.
4. Market Impacts - Impacts that are linked to market transactions and directly affect gross domestic product (GDP, a country's national accounts)--for example, changes in the supply and price of agricultural goods.
5. Non-Market Impacts- Impacts that affect ecosystems or human welfare, but that are not directly linked to market transactions--for example, an increased risk of premature death.

1.9.6 Climate Variability.

Levina and Tirpak (2006), defined climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

1.10 Area of Study

1.10.1. Area of Study

Enugu is the capital of Enugu State in Nigeria. It is located in the southeastern area of Nigeria and is largely populated by members of the Igbo, an ethnic group in Nigeria. From being the capital of the Southern Province, Enugu became the capital of the Eastern Region (now divided into nine States), and Capital of the defunct Republic of Biafra, thereafter it became the capital of East Central State, Anambra State, (old) Enugu State, and now the present Enugu State through a process of state creation and diffusion of administrative authority (Nwokeabia, nd.).

Enugu state is located at Latitude: 6°26′28″ N and Longitude: 7°29′55″ E Elevation above sea level: 192 m, 629 ft. The Coordinates of Enugu in decimal degrees are: Latitude: 6.4413200° and Longitude: 7.4988300°. The Coordinates of Enugu in degrees and decimal minutes are: Latitude: 6°26.4792′ N and Longitude: 7°29.9298′ E.

The city has a population of 722,664 according to the 2006 Nigerian census. The name *Enugu* is derived from the two Igbo words *Enu* and *Ugwu* meaning "top of the hill" or *Hill top*, denoting the city's hilly geography. Enugu State shares boarders with Abia State and Imo State to South, Ebonyi State to the east, Benue State to the northeast, Kogi State to the North West and Anambra state to the west. There are 17 local government area in Enugu State. These are Aninri, Agwu, Enugu East, Enugu North, Enugu South, Ezeagu, Igbo Etiti, Igbo-eze North, Igboeze South, Isi-Uzo, Nkanu East, Nkanu West, Nsukka, Oji-River, Udenu, Udi, Uzo-Uwani

1.10.2 Geographical Location

Enugu state is located at Latitude: 6°26′28.75″ N and Longitude: 7°29′55.79″E. Elevation above sea level: 192 m = 629 ft. The Coordinates of Enugu in decimal degrees are: Latitude: 6.4413200° and Longitude: 7.4988300°. The Coordinates of Enugu in degrees and decimal minutes are: Latitude: 6°26.4792′ N and Longitude: 7°29.9298′ E.

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1.10.3 Climate

Enugu is located in a tropical rain forest zone with a derived savannah. The city has a tropical savanna climate. Enugu's climate is humid and this humidity is at its highest between the months of March and November. For the whole of Enugu State the mean daily temperature is 26.7 °C (80.1 °F).As in the rest of West Africa, the rainy season and dry season are the only weather periods that recur in Enugu. The average annual rainfall in Enugu is around 2,000 millimeters (79 in), which arrives intermittently and becomes very heavy during the rainy season. Other weather conditions affecting the city include Harmattan, a dusty trade wind lasting a few weeks in the months of December and January. Like the rest of Nigeria, Enugu is hot all year round.

1.10.4 Geology and Soils

Enugu State occupies much of the highlands of Awgu, Udi and Nsukka. The hills are flanked by the rolling lowlands of Oji River, Adada and Anambra Basins to the west, and the Ebonyi (Aboine) River Basin to the east. The area contains about nine geological formations. From east to west, and in terms of age and sequence of expo sure, the formations are: the Asu River Group of the Albian (Lower Cretaceous) Age, made up of shales, sandstones and siltstones.

The sediments later became folded, giving rise to the Abakaliki anticlinorium and the related Afikpo synclinorium both within the present Ebonyi State, as well as the syclinal basin lying between the Niger and EzeAku shales formation of the Turonian Age which contains shales, siltstones, of sandstones and limestones.

Awgu Ndeaboh Shales Formation of the ie Coniacian Santonian Age. Enugu Shales (to the North) and Awgu Sandstones (to the South) along the ie same axis. They were laid in the Campanian substage. Lower Coal Measures Formation (Mamu reFormation) of the Meastrichtian Age.

This is the coal bearing formation. False bedded Sandstones Formation is (Ajali Sandstones) also of the Meastrichtian Age. The body of the sand stone is thick, friable and poorly sorted. Upper Coal Measures Formation (Nsukka is Formation) of the Nadian Age.

The formation consists of coarse sandstones or with shale intercalations and fragments of iron stones and ferruginized shales and not sandstones. It abounds extensively on ct the Udi-Nsukka

Plateau where differential the erosion has left the resistant portions n standing out as rounded, conical, domey, is cuestalike, elongated and sometimes a flat topped hills, some hundreds of of metres above the general level.

These are Upper Cretaceous Sediments were probably uplifted during the Tertiary formation, giving rise to the Enugu-Okigwe escarpment is 8 Imo Shale Clay Formation of the Pleistocene Age. It is about 1,000 metres in thick and overlies the Upper Coal Je Measures conformably. , Alluvium Deposits which belong to the ia Recent Age. In Enugu State, this formation occurs farthest to the northwest, and belongs to the Niger Anambra flood plain (Ofomata, 1975).

The soils are made up of shallow and stony lithosols found on the steep slopes of the cuesta and often left uncultivated, the ferrallitic soils, also called Red Earth or Acid Sands, found on the plateau, and the hydromorphic soils of the flood plains.

Soil erosion, both from physical and manmade causes, is rampant in several parts of the state. It shows in rills along roadside embankments, in sheet wash across compounds and farmlands, and in gullying, sometimes very dramatic, along definitive channels and zones

Enugu has good soil-land and climatic conditions all year round, sitting at about 223 metres (732 ft) above sea level, and the soil is well drained during its rainy seasons. The mean temperature in Enugu State in the hottest month of February is about 87.16 °F (30.64 °C), while the lowest temperatures occur in the month of November, reaching 60.54 °F (15.86 °C). The lowest rainfall of about 0.16 cubic centimetres (0.0098 cu in) is normal in February, while the highest is about 35.7 cubic centimetres (2.18 cu in) in July.

1.10.5 Vegetation

The vegetation on the highlands of Awgu and stretching through its rocky promontories to link with the undulating hills of Udi, is of the semitropical rainforest type. It is characteristically green and is complemented in the Nsukka area by typical grassy vegetation. Fresh water swamp forests occur in the Niger Anambra Basin.

1.10.6 Economic Activities and Development

Nicknamed the *Coal City*, Enugu's economy in the early 20th century depended on coal mining in the Udi plateau; this industry was the pushing force towards the city's growth. The Nigerian Coal Corporation has been based in Enugu since its creation in 1950 where it controlled coal mining. With the creation of the Enugu-Port Harcourt railway, Enugu was connected with the sea via Port Harcourt to its south and later connected to the city of Kaduna to Enugu's north. The Biafran war brought widespread devastation that forced a decline in coal production from damage or destruction of equipment. As of 2005, coal mining is no longer the major source of income and mines lay unused. Other minerals mined in Enugu include iron ore, limestone, fine clay, marble, and silicas and.In Enugu most goods are sold in open markets or by; a significant number of street hawkers in Nigeria are children. As of 2003, around 44 under-16-year-olds (equally boys and girls) hawk on every street on every hour in Enugu. There are three main urban markets in Enugu: Ogbete Market, Awkunanaw Market and New Market. New Market is a major market for the sale of garri. Ogbete market is patronised by merchants from all over the surrounding area, including merchants from cities like Onitsha, Aguleri, Abakaliki and Aba. In Ogbete market non-food goods are also sold. Textile manufacturing, food processing, lumbering, soft-drink bottling, brewing, and furniture manufacturing are among other industries in the city. For a period of time Sosoliso Airlines had its head office on the grounds of Akanu Ibiam International Airport in Enugu.The former Eastern Region was once famed for producing half the world's total output of palm kernels. Since the Nigerian-Biafran War production has markedly declined largely because the plantations and processing equipment were either damaged or destroyed. The production of other important cash crops such as cocoa, groundnut and groundnut oil, rubber, cassava, cotton and cotton seed and timber tumbled after the civil war and the subsequent oil boom years. Consequently, the area called Enugu State as well as the rest of Nigeria, which was once a self-sufficient net exporter in agricultural produce, must import food. The map of Enugu metropolis.

Fig 1.2: Map of Nigeria showing Enugu State.

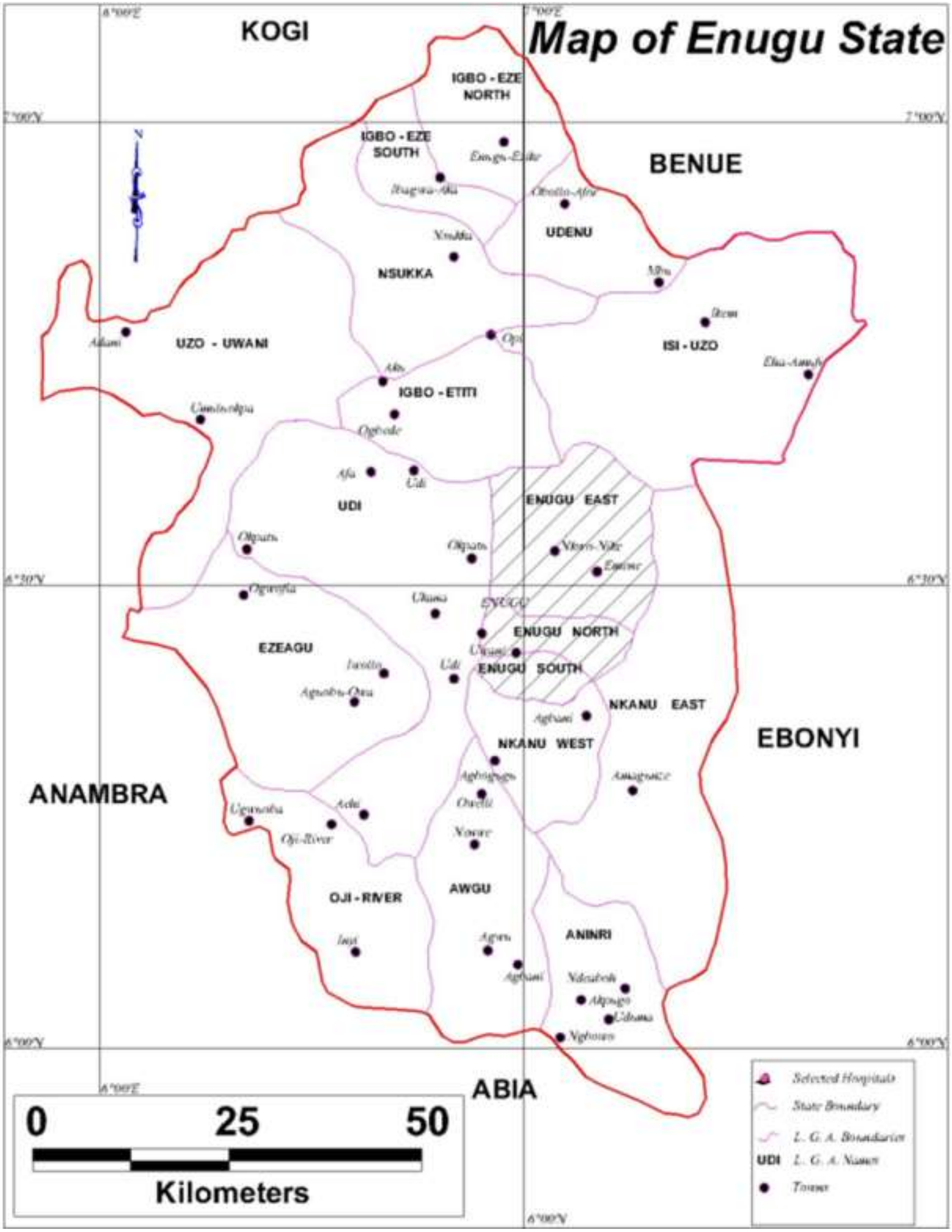

Fig 1.3: Map of Enugu showing Enugu Urban Area.

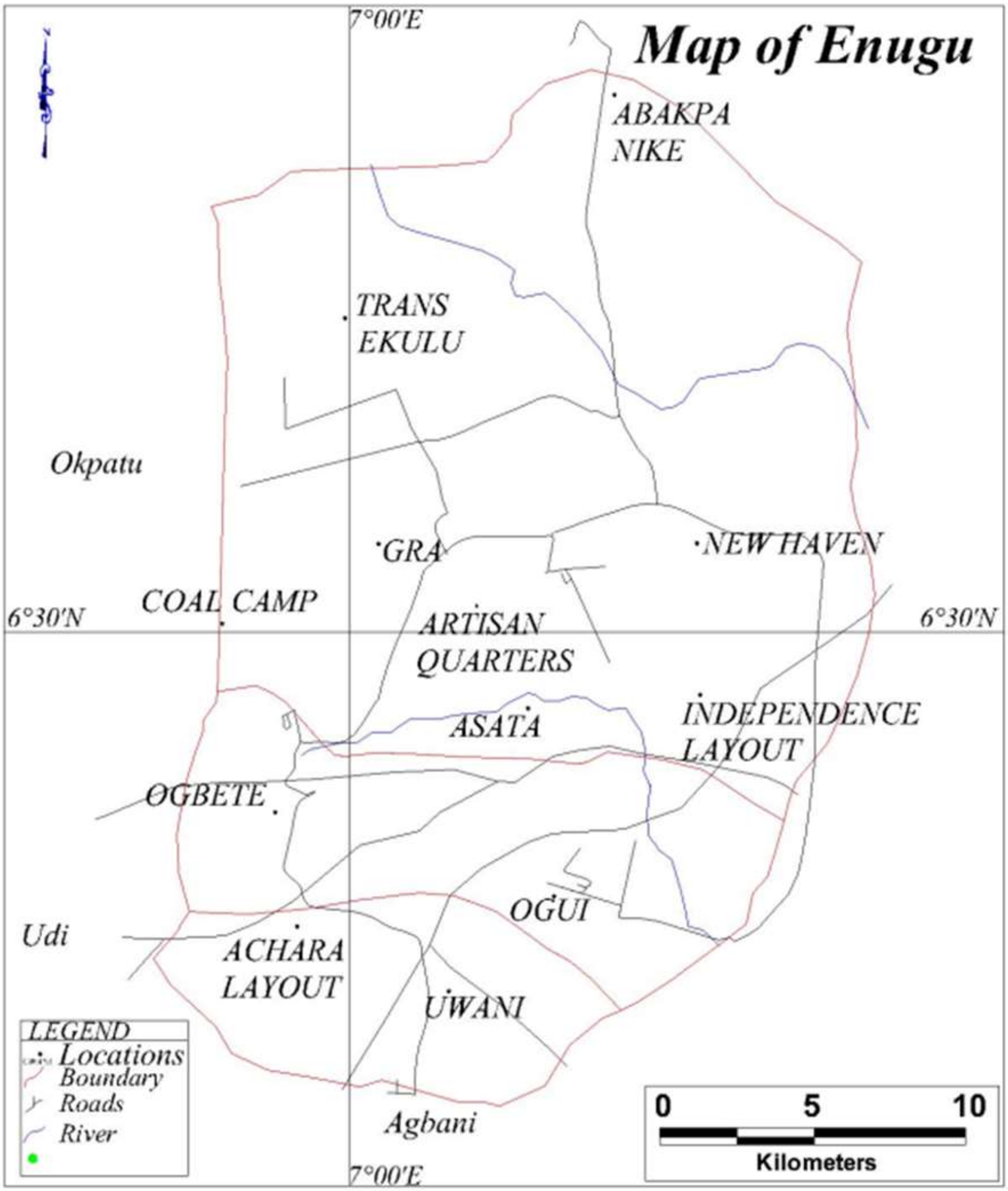

Fig 1.4: Map of Enugu Urban Area.

1.11.1 Structure of the Thesis

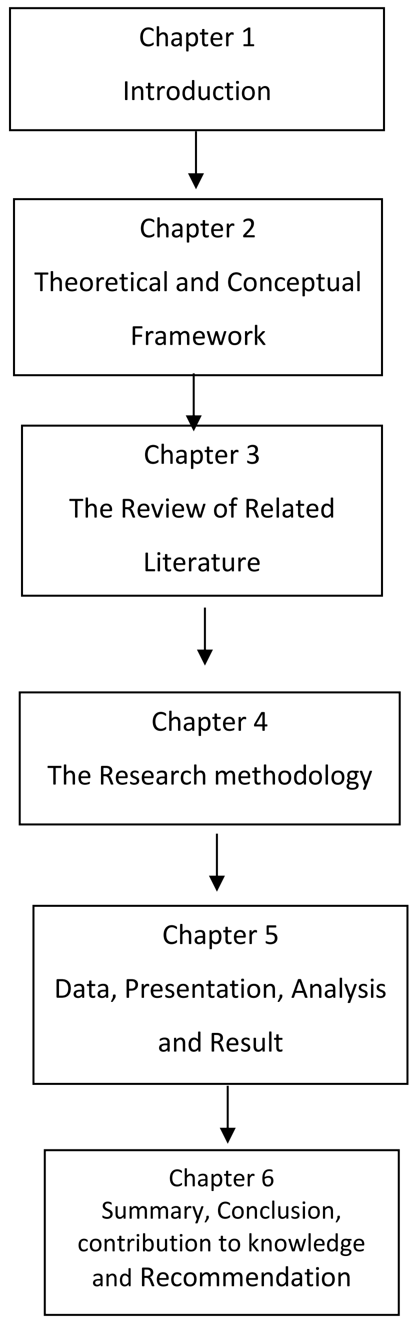

Fig 1.1 Flow chart of the dissertation structure

This dissertation is in six chapters. The first, chapter one (1) is the introduction of the subject matter, the background of the research, which sets the general evidence of variations in climatic factors and its relationship with building construction. It further states the problems that motivated the research, the aim to be achieved and designed objectives through which the aim can be reached. It also contains the research questions, and the hypothesis. The justification, discusses the importance of the research to all the stakeholders and the public. Finally, the chapter concludes with a delimitation of the scope of the study, structure of the thesis, and the area of study.

Chapter 2 introduces the theoretical and conceptual basis on which the research was anchored. The chapter evaluates the theory of cause and effect and its relevance to climate change as well as some related concepts: variability, vulnerability, mitigation, adaption and impact among other.

Chapter 3 basically handled two issues: the causes and the effects of climate change. The two causes outlined: anthropogenic and natural causes. These causes affect building design, cost of construction, materials used, operational energy and cost of maintenance. The general related academic literature on the subject matter was reviewed and that helped the researcher to generate gaps.

Chapter 4 describes the methodology for this research, the approach to be employed, the research philosophy, research need, population size and techniques. It also handled in details the method of data collection, stated the validity and reliability of instrument, finally the method of analysis and presentation.

Chapter 5 presents an analysis of the data collected in chapter four (4), the responses from questionnaire and the data from NIMET. The chapter further presents data, analyses and discussions of research results including the test of hypotheses.

Chapter 6 presents a general overview of the research, also presents the summary of findings, conclusions and recommendations and contribution to knowledge.

CHAPTER TWO

2.0 THEORETICAL/CONCEPTUAL FRAMEWORK

This section discusses the concepts upon which this work was built and also gives concise definition of some important terminologies used in further discussions of the basic concept of Climate Change. To better address the topic of study and for comprehensive understanding, the concepts of Vulnerability, Adaptation and Mitigation were explored.

2.1 Theoretical Framework

2.1.1 Theory of Cause and Effect

This research is based on the theory of cause and effect. This theory proposes logical fact that for an effect to exist there must be a cause. According to Williams (2017), in his paper on cause and effect relationship, he explained a cause-effect relationship is a relationship in which one event (the cause) makes another event happen (the effect). One cause can have several effects. He also pointed that in order to establish a cause-effect relationship, three criteria must be met. The first criterion is that the cause has to occur before the effect. This is also known as temporal precedence.

Second, whenever the cause happens, the effect must occur. Consequently, if the cause does not happen, then the effect must not take place. The magnitude of the cause also determines the magnitude of the effect. The final criterion is that there are no other factors that can explain the relationship between the cause and effect. This is a little trickier, because the third is hardly met.

The cause and effect theory can be analyzed using fishbone diagram by Ishikawa as shown in figure 2.1, which is generally called fishbone diagram (because of its resemblance to a fish skeleton) or Ishikawa diagram, after its inventor Ishikawa, (1990). It shows the relationship of all factors (causes) that lead to the given situation (effect). It identifies major causes and breaks them down into sub-causes and further sub-divisions (if any). It is usually preceded by cause-and-effect analysis. (1915-89) of Tokyo's Mushasi Institute.

According to Tague (2005), the fishbone diagram identifies many possible causes for an effect or problem. It can be used to structure a brainstorming session. It immediately sorts ideas into useful categories. This diagram is used:

1 When identifying possible causes for a problem.

2 Especially when a team’s thinking tends to fall into ruts.

2.1.2 The Fishbone Diagram and Application

This is used to identify and analyze the causes of problem. It graphically illustrates the hierarchical relationship between an existing problem and the cause/causes. This technique uses a diagram-based model to analyze problems.

STEP1: State the Problem

Fig. 2.1 Statement of Problem

Identity the problem prompting the research to represent(x), the problem is the effects of climate change on building. The arrangement will look like the head and spine of a fish.

2.1.3 Identification of the causes of the problem

The second step identifies the relative causes of climate change which are:

1. Anthropogenic causes

2. Natural cause

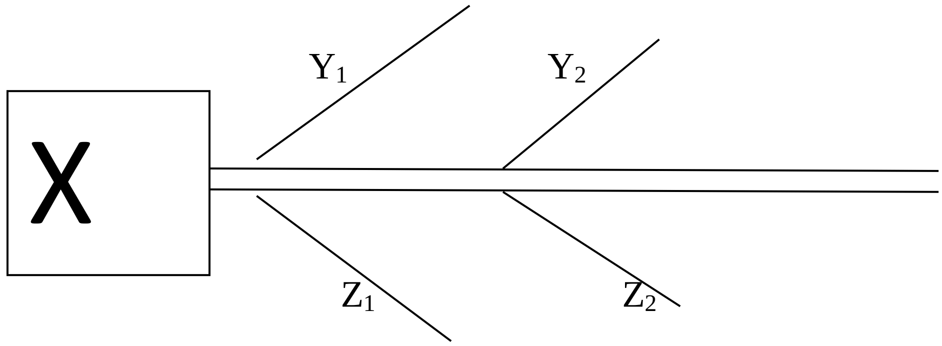

Fig. 2.2: Problem identification

The line labeled Y_1 and Y_2 represent the causes of climate change which includes: anthropogenic (Y_I) and natural causes (Y_2) and Z_1 (building cost and pattern) and Z_2 (variability) represent the effect of climate change on building. This is represented using lines drawn to look like the "spine of a fish".

2.1.4: Categories of possible causes and effects

The possible categories of causes and effects of climate change are outlined and minor lines are drawn from the major line (the large fish bone) on the diagram to show them.

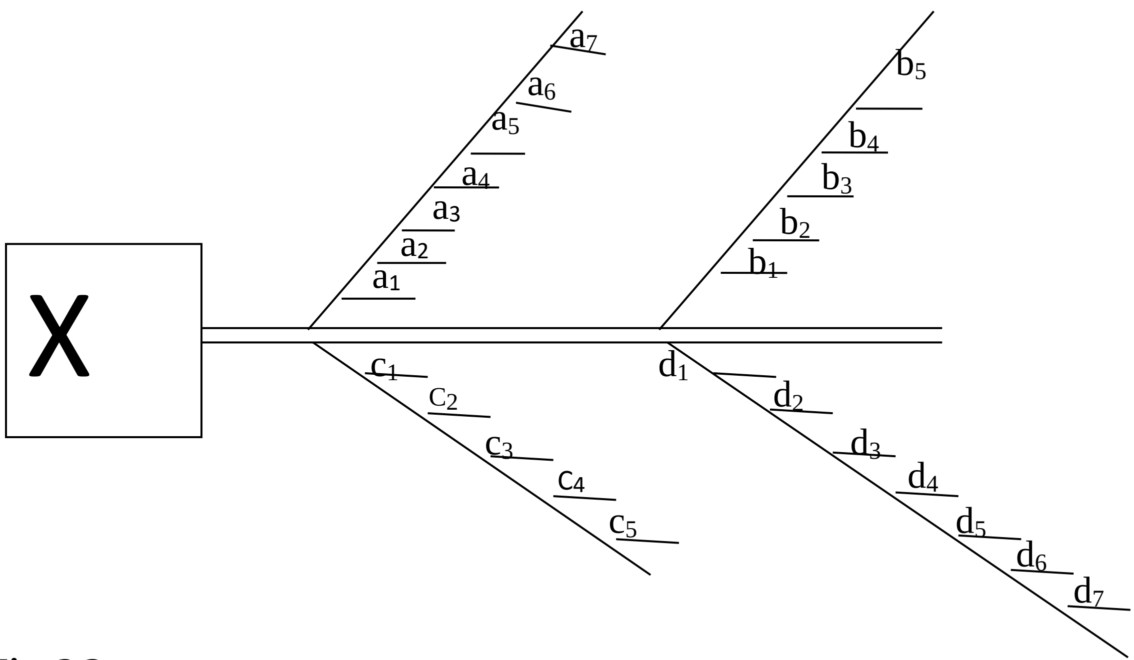

Fig. 2.3 Categories of possible causes and effects

Step three identified the possible categories of causes and effects of climate change. This was shown with small lines drawn from the main line and each representing possible cause or effects of climate change and labeled accordingly. This completely illustrates the whole idea. The small lines a_1 to a_7 represent the possible contributors of natural cause (Y_1). The lines labeled b_1 to b_5 show the possible contributors of anthropogenic cause (Y_2). The lines labeled c_1 to c_5 represent the effects of climate change (z_1) and lines f_1 to f_7 show effect on building cost and pattern (z_2) respectively.

2.1.5: Analysis of the Diagram

The diagram has fully illustrated the possible causes and effects of climate change.

Figure 2.1, which is the box, marked (x) with the long horizontal line forming the fish head and spine represents the problem of study: effects of climate change on building construction. The main lines Y_1 and Y_2 represent the causes of climate change: natural (Y_1) and anthropogenic (Y_2), Z_1 and Z_2 represent the effects on climate variability (Z_1) and cost (Z_2).

The minor lines a_1 to a_5 represent the natural causes a_1 (carbon dioxide), a_2 (water vapor), a_3 (methane), a_4 (nitrous oxide), and a_5 (chlorofluorocarbons) among others. The lines: b_1 to b_7 represents the anthropogenic causes, b_1 (construction), b_2 (deforestation), b_3 (mining), b_4 (drilling), b_5 (agriculture), b_6 (dredging), b_7 (tourism) among others.

The minor lines c_1 to c_7 on climate variability: c_1 (rising temperature), c_2 (fluctuation in rainfall), c_3 (wind storm), c_4 (flood), c_5 (drought), c_6 (coastal erosion), c_7 (subsidence) among others. The lines: d_1 to d_5 represents the effects of climate change on building construction based on the chosen criteria for analysis, d_1 (building design), d_2 (cost of construction), d_3 (energy in use), d_4 (building materials), d_5 (maintenance cost) among others.

In summary, fishbone diagram is used to illustrate that there is a relationship between cause and effect. Climate change doesnot just exist; it is caused by a number of other factors which the fishbone diagram was used to illustrate. Therefore, there exists a cause for every effect, justifying the relevance for this study.

2.2.1 Conceptual Framework

2.2.1.1The concept of Low Carbon Future (LCF) and Adaptation and Resilience in Energy Systems (ARIES)

The above model proposes that a detailed thermal model of an individual building and a stock of model of many buildings is a dynamic, local-scale stock model. The building modelers interested in future climates which usually is on overheating or under heating of buildings and the low carbon future tools provides a function in this respect. This factors in the future technologies that are likely to have effects on electrical and thermal demand profiles of a building.

According to the model by Jenkins, Patidar & Simpson (2015) on "Quantifying Change in Buildings in a Future Climate and Their Effect on Energy Systems" at Heriot-Watt University, Edinburgh, their research in a simplified form, presents the ability of the tools/methods to influence decision making for future design. The approach is flexible enough to account for different future scenarios, and can assist a designer in choosing features (or adaptations) that might suit a building (or buildings) for a future climate. Furthermore, the impact that this might have on an energy network, for that given future scenario, can be explored. As previously discussed, more work is required to expand the application of this method.

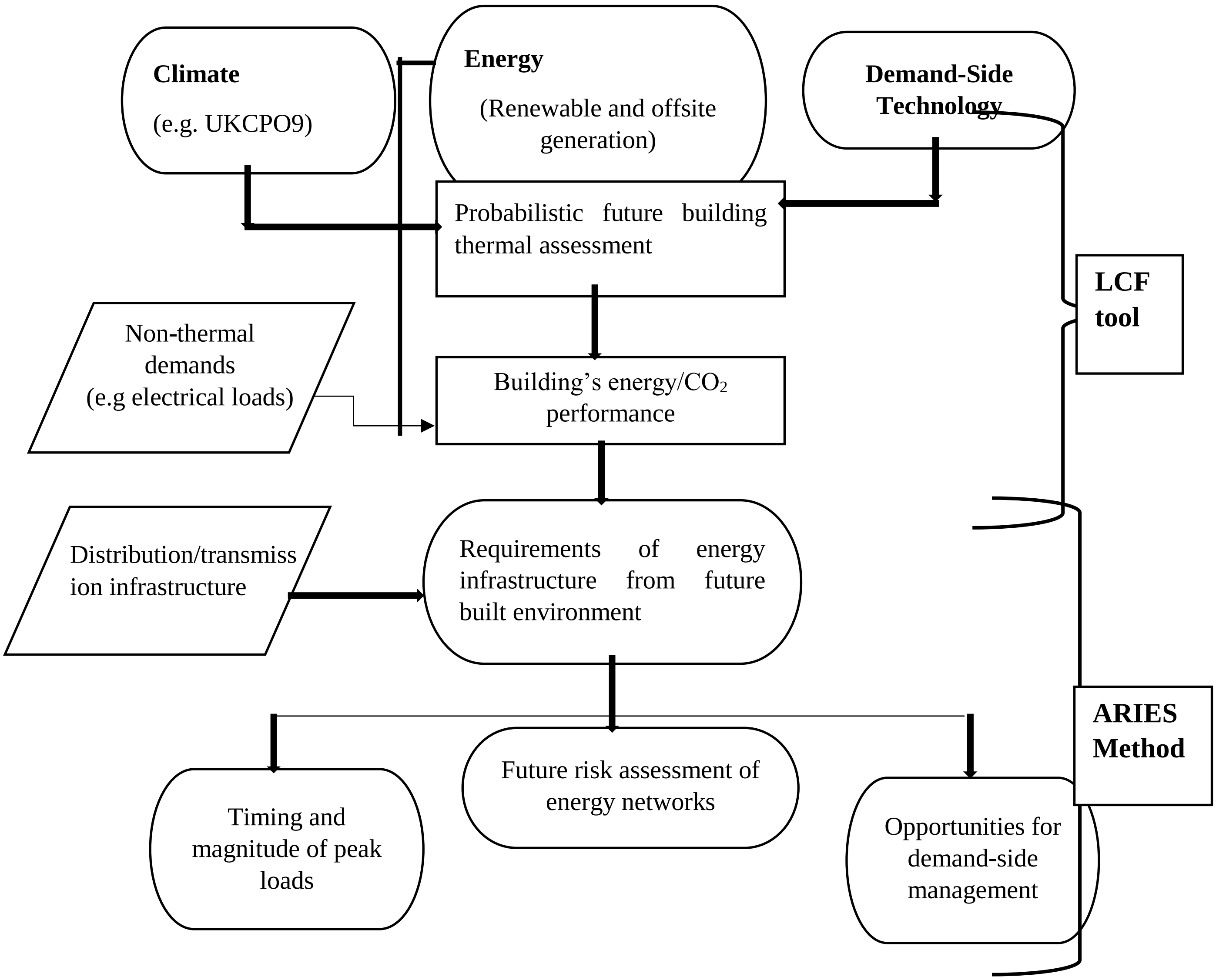

Fig. 2.4 A model showing the use of LCF and Adaptation and Resilience in Energy Systems (ARIES) methodologies for identifying future forms of energy provision for the built environment.

2.2.1.2 The Concept of Mitigation

The concept of mitigation proposes that land degradation and climate change affects poverty. Climate change mitigation permits more stable climate pattern which would avoid undesirable conditions and thus encourages sustainable land management practices. It is important to recognize that all human activities, and more precisely economic activities, are embedded in the greater Earth System. As they are transformed, natural resources flow as inputs and outputs of the economy. Limits to economic activity and economic growth coincide with limits to the absolute availability of, and accessibility to, natural resources, despite technological progress achieved [i.e. growth in land productivity is expected to continue, although at a declining rate (Smith et al, 2007)]. The voracious appetite of the dominant global economic model is leading, on one hand, to ever-increasing environmental degradation, which affects the own economy's productive capacity; and on the other, to increased societal inequalities, as people living in poverty, and who are highly dependent on natural resources for subsistence, feel the impact of reduced access to resources and reduced income more profoundly. In opposition, a sustainable model of economic growth is one that regards the environment as a valuable input for economic activity production (Kahn, 2004), thus promoting environmental preservation.

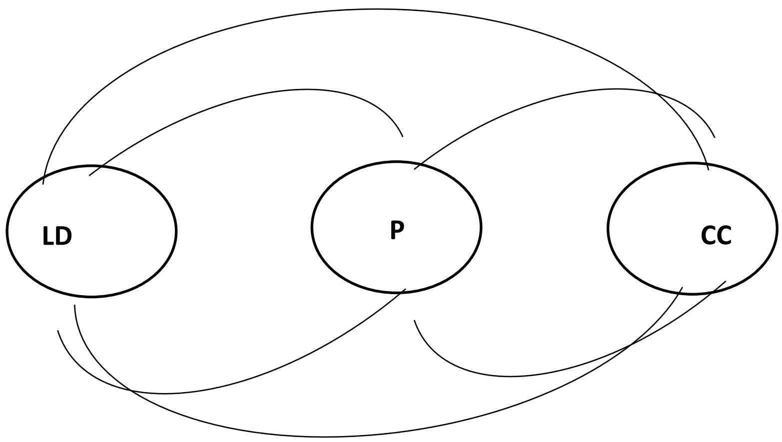

Fig. 2.5: A Model for Assessing Schematic cause-effect relationships between land degradation (LD), poverty (P) and climate change (CC). Width of arrows indicates the strength of relationship.

2.2.1.3 The Concept of Adaptation

The above concept discusses barriers to adaptation as lack of consistent, up to date and appropriate information and knowledge. They also argued that there is no clear and well-accepted definition for climate-adaptable buildings as it is interchangeably used as climate resilient buildings. Different external stimuli for adaptable buildings and different forms of adaptability in approach. Lelieveld, Voorbij & Poelman (2007) define Adaptable Architecture as "an architecture from which specific components can be changed in response to external stimuli, for example the user or environment.

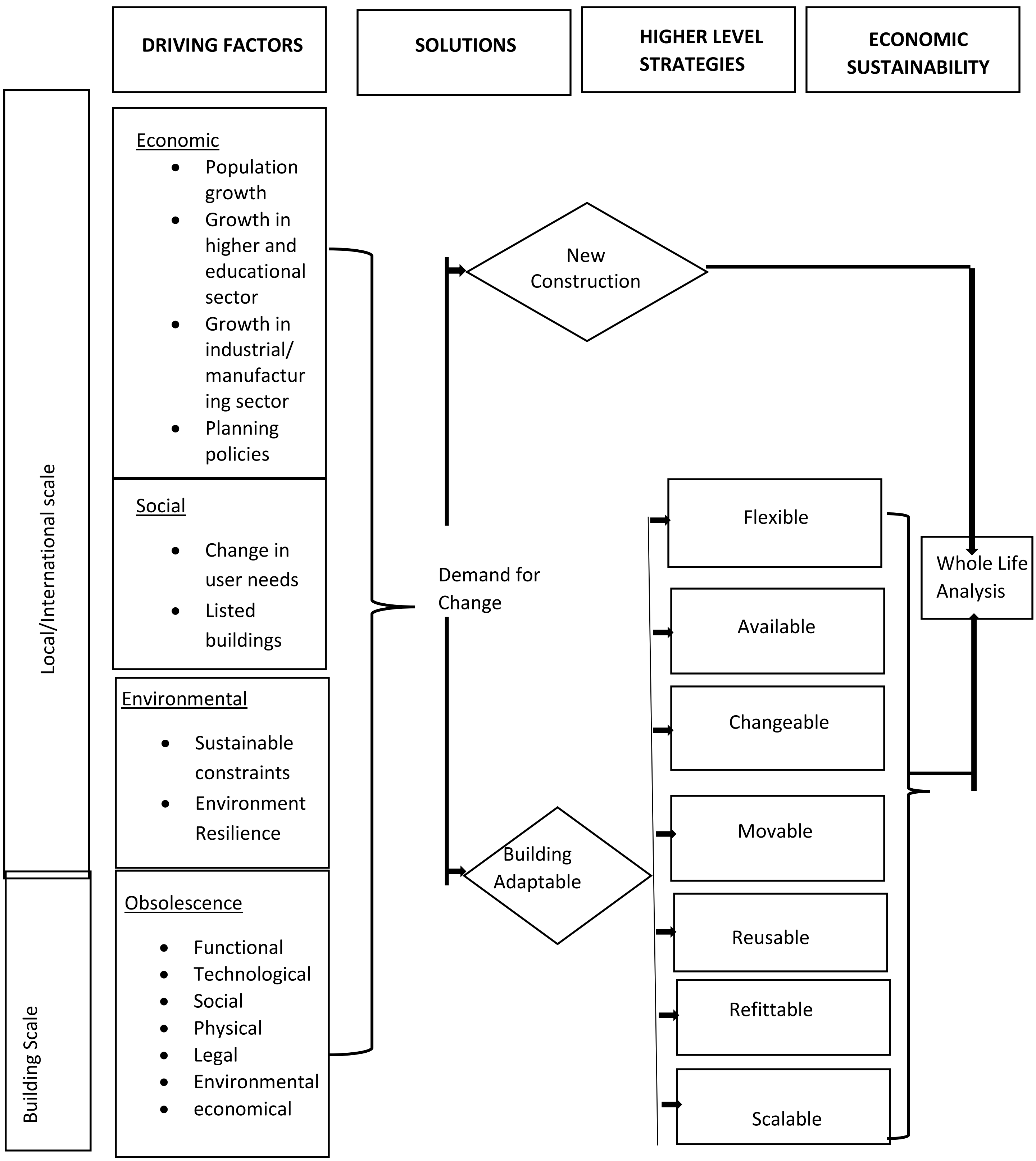

Fig. 2.6: A Model for Assessing the Climate Change Adaptability of Buildings

Levels of adaptation in order of sophistication (Lelieveld, Voorbij & Poelman 2007) Omi (2007) presented a prototype "self-standing self-build" infill unit to propose a method of realising adaptable buildings, which includes prefabricated, modular 'infill' elements that remain structurally separate from the 'skeleton' of the building and as a result provide flexibility of assembly, disassembly or reconfiguration as required.

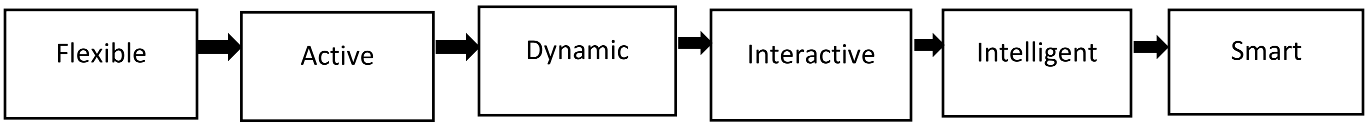

Fig. 2.7 Model for assessing the Levels of adaptation in order of sophistication

The three concepts discussed basically stated that for an effective adaptation, more resilient and robust buildings are to be constructed which are better able to withstand the effects of projected climate change impacts throughout their lifecycle. The concept of mitigation proposes avoidance of activities which cause changes in climate variabilities, the concept of low carbon future suggests tools and methods that compares different buildings at varying locations, it also factors in technologies which likely manages the thermal demand profile of buildings. All the three concepts discussed suggested some mitigation and adaptation factors, this research brought in all the effects and their impacts on building in relationship with building designs, building materials, construction cost and energy demands in buildings.

CHAPTER THREE

3.0 REVIEW OF RELATED LITERATURE

This chapter reviews related works of different scholars in many places with a view to identify gaps. The review was done under the following sub-heading:

1. Causes of Climate Change
2. Effects of Climate Change on Buildings
3. Adaptation to climate change
4. Summary of literature
5. Literature gaps

3.1 Climate Change

Climate change involves extreme shift in these climate variables due to natural or human factors. Climate change is intensifying as manifested in rising temperatures, fluctuations in rainfall, floods, droughts, and wind storms (IPCC, 2013). Long term alteration in global weather patterns, especially increases in temperature and stormy activity, regarded as a potential consequence of greenhouse effect is referred to as climate change, Adedeji and Ogunsote (2012). According to Levina and Tirpak (2006), climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. (IPCC TAR, 2001).

It was also defined as a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land-use. (IPCC TAR, 2001 b)

Climate change is seen as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. In another opinion, climate change of a place or region is changed if over an extended period (typically decades or longer) there is a statistically significant change in measurements of either the mean state or variability of the climate for that place or region. (Changes in climate may be due to natural processes or to persistent anthropogenic changes in atmosphere or in land use. Note that the definition of climate change used in the United Nations Framework Convention on Climate Change is more restricted, as it includes only those changes which are attributable directly or indirectly to human activity.) (UN/ISDR, 2004)

The UNFCCC makes a distinction between climate change that is attributable to human activities altering the atmospheric composition of the globe and ‘climate variability’ attributable to natural causes, a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (UNFCCC).

By contrast, the IPCC takes a broader view on ‘climate change’ and states that climate change can occur as a result of natural variability and human activity. These different definitions have implications for defining ‘adaptation’ as a policy response to climate change, just as Pielke (2004) noted in his publication “What Is Climate Change”, “Under the FCCC definition, ‘adaptation’ refers only to new actions in response to climate changes that are attributed to greenhouse gas emissions. Under the logic of the FCCC definition of climate change, adaptation represents a cost of climate change, and other benefits of these adaptive measures are not counted. From the restricted perspective of the FCCC, it makes sense to look at adaptation and mitigation as opposing strategies…” He also states that “From the broader IPCC perspective on climate change, adaptation policies also have benefits to the extent that they lead to greater resilience of communities and ecosystems to climate change, variability, and particular weather phenomena.”

Füssel (2007), in his report on the Intergovernmental Panel on Climate Change (IPCC,2007), defined climate change as any change in climate over time, whether due to natural variability or as a result of human activity. He further pointed out that when climate change is discussed, they are referring to observed and projected increase in average global temperature as well as associated impacts (e.g. an increase in the frequency or intensity of extreme weather; melting icebergs, glaciers and permafrost; sea-level rise; and changes in the timing or amount of precipitation).

The extreme weather conditions include global warming, drought, desertification, flood, sea-level rise, wind and rainstorm and thunderstorm among others (Akpodiogaga & Odjugo, 2009). On their paper titled “Quantifying the Cost of Climate Change Impact in Nigeria”: Emphasis on Wind and Rainstorms, they argued that Wind related hazards have not been adequately acknowledged as environmental problem like flooding and gully erosion that needs to be properly addressed by the Nigerian Government.

3.2 Causes of Climate Change

From available literature it has been proven that climate change is caused by both natural and anthropogenic factors. According to Odjugo (2010), in his paper on "General Overview of Climate Change Impacts in Nigeria" stated that Climate change is caused by two basic factors, which include natural processes (biogeographical) and human activities (anthropogenic). This review therefore will be based on these two categories of causes, the natural and the anthropogenic causes of climate change as follows:

3.2.1 Natural Causes of Climate Change

3.2.1.1 Greenhouse Gases

CCIR (2005), in their report on what causes global climate change stated that the presence of greenhouse gases in the atmosphere is a natural component of the climate system and helps to maintain the Earth as a habitable planet. According to their report, greenhouse gases are relatively transparent to incoming solar radiation, allowing the sun's energy to pass through the atmosphere to the surface of the Earth. The energy is then absorbed by the Earth's surface, used in processes like photosynthesis, or emitted back to space as infrared radiation. Some of the emitted radiation passes through the atmosphere and travels back to space, but some are absorbed by greenhouse gas molecules and then re-emitted in all directions. The effect of this is to warm the Earth's surface and the lower atmosphere. Water vapor (H_2O) and carbon dioxide (CO_2) are the two largest contributors to the greenhouse effect. Methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs) and other greenhouse gases are present only in trace amounts, but can still have a powerful warming effect due to their heat-trapping abilities and their long residence time in the atmosphere. Without the greenhouse effect, Earth's average temperature would be -0.4°F (-18°C), rather than the present 59°F (15°C).

IPCC (2007), in their contribution on the Physical Science Basis of Climate Change, stated that human activities contribute to climate change by causing changes in Earth's atmosphere in the amounts of greenhouse gases, aerosols (small particles), and cloudiness. The largest known contribution comes from the burning of fossil fuels, which releases carbon dioxide gas to the atmosphere. Greenhouse gases and aerosols affect climate by altering incoming solar radiation and outgoing infrared (thermal) radiation that are part of Earth's energy balance. Changing the atmospheric abundance or properties of these gases and particles can lead to a warming or cooling of the climate system. Since the start of the industrial era (about 1750), the overall effect of human activities on climate has been a warming influence. The human impact on climate during this era greatly exceeds that due to known changes in natural processes, such as solar changes and volcanic eruptions.

In line with the opinion of IPCC (2007), the Royal Society and the US National Academy of Sciences (2008) in their overview on climate change evidence and causes, noted that the observed global surface temperature rise since 1900 is consistent with detailed calculations of the impacts of the observed increase in atmospheric CO_2 (and other human-induced changes) on Earth's energy balance. According to them, different influences on climate have different signatures in climate records. These unique fingerprints are easier to see by probing beyond a single number (such as the average temperature of Earth's surface), and looking instead at the geographical and seasonal patterns of climate change. The observed patterns of surface warming, temperature changes through the atmosphere, increases in ocean heat content, increases in atmospheric moisture, sea level rise, and increased melting of land and sea ice also match the patterns scientists expect to see due to rising levels of CO_2 and other human-induced changes. This confirms the assertion that climate change is a product of anthropogenic activities. The expected changes in climate are based on our understanding of how greenhouse gases trap heat. Both this fundamental understanding of the physics of greenhouse gases and fingerprint studies show that natural causes alone are inadequate to explain the recent observed changes in climate.

Gonitz (2009), stated that the reconstructions of volcanic, solar, and greenhouse gas forcing have enabled testing of the relative importance of different mechanisms for climate change. The volcanic reconstructions are based on sulfate deposited in Greenland and Antarctic ice cores. Solar variability can be inferred from variations of the cosmogenic isotopes ^{14}C and ^{10}Be. Trace gas concentrations are derived from ice cores. Experiments with both simple and complex climate models indicate that there is a surprisingly large forced response in the decadal-centennial band.

Subsequently, Crowley, Baum, Kim, Hegerl and Hyde (2003), while modeling ocean heat content changes during the last millennium, found that more detailed analyses indicate that changes in volcanism can explain about 40% of the variance in the interval 1,000–1,850 (prior to the enhanced disturbance of the system following the industrial revolution). By contrast, solar variability and trace gas changes play only a secondary role on the largest scale although there are some evidences that solar variability may occasionally be proportionately more important on smaller space scales, this is buttressed in the work of Hegerl, Crowley, Baum, Kim, and Hyde (2003).

Odjugo (2010), noted that the natural processes are the astronomical and the extraterrestrial factors. The astronomical factors include the changes in the eccentricity of the earth's orbit, changes in the obliquity of the plane of ecliptic and changes in orbital procession while the extra-terrestrial factors are solar radiation quantity and quality among others.

3.2.1.2 Tectonic Time Scale

According to Gonitz (2009), CO_2 appears to play perhaps the dominant role as the first-order "driver" of climate change on tectonic timescales. However, CO_2 cannot explain everything. In particular, the altered planetary temperature gradient during warm time periods indicates a response of the ocean-atmosphere system that represents perhaps the most prominent difference between models and observations in the pale climate record. Understanding this response may enable more confident predictions of greenhouse model simulations of the future. A second important consideration of climate change on tectonic timescales involves the rapid transitions to ice cover at various times in the Phanerozoic. Models suggest that this transition may be explicable by snowline instability due to albedo discontinuities at the snow-ice edge. This instability has received much less attention than changes in the ocean circulation, but is fully deserving of equal prominence as a mechanism for rapid climate change.

3.2.2 Anthropogenic Causes of Climate Change

Climate change is caused by an increase of certain greenhouse gasses such as carbon dioxide and methane in the atmosphere. On the other hand Odjugo (2010), wrote that the anthropogenic factor in climate change involves human activities that either emit large amount of greenhouse gases into the atmosphere that depletes the ozone layer or activities that reduce the amount of carbons absorbed from the atmosphere. The human factors that emit large amounts of greenhouse gases include industrialization, burning of fossil fuel, gas flaring, urbanization and agriculture. On the other hand, human activities that reduce the amount of carbon sinks are deforestation, alterations in land use, water pollution and agricultural practices. The human factors have been proven to be responsible for the ongoing unequivocal climate change or global warming (IPCC 2007).

Nzoiwu and Ezenwaji (2017), on their paper titled "contributions of anthropogenic fact to the observed surface area variation of Agulu Lake, Anambra State", argued that the increasing need for agricultural produce has encouraged irrigations and the huge water withdrawn from lakes contributes to the observed shrinking of the lakes surfaces. They further stated that understanding anthropogenic factors are important for a proper and better maintenance of the water richness of the lake. They generated monthly records of air temperature, relative humidity, sunshine duration, wind speed and rainfall from the meteorological station. The extent of relationship between the surface area of the Agulu lake and climate variables were examined. The findings includes: 47% of the variation in surface area of Agulu lake from 1978-2013 is connected to the direct influence of variation in temperature, rainfall and evaporation.

The research did not take the individual strength of temperature, rainfall and evaporation into account. Their work recommended a need to examine the respond of Agulu Lake to changes in catchment characteristics such as forest deforestation impact of development around the lake and potential threat, if any posed by Agulu-nanka gully erosion system to the lake.

Some of the activities of man increase the content of these greenhouse gases in atmosphere. Some researchers who worked in this area found these anthropogenic factors to include:

3.2.2.1 Combustion of Fossil Fuel

CCIR (2005), reported that the concentrations of greenhouse gases, especially carbon dioxide have risen over the past two hundred and fifty years, largely due to the combustion of fossil fuels for energy production. Since the Industrial Revolution in the eighteenth century the concentration of carbon dioxide in the atmosphere has risen from about 270 parts per million (ppm) to about 370 ppm. Concentrations of methane have also risen due to cattle production, the cultivation of rice, and release from landfills. Nearly one-third of human-induced nitrous oxide emissions are a result of industrial processes and automobile emissions. This is in agreement with the report of (IPCC, 2001; and NAS, 2001).

3.2.2.2 Land-Use Change

In the report of CCIR (2005), on causes of climate change, they noted that the combustion of fossil fuels is not the only anthropogenic source of carbon dioxide. When ecosystems are altered and vegetation is either burned or removed, the carbon stored in them is released to the atmosphere as carbon dioxide. The principal reasons for deforestation are agriculture and urban growth, and harvesting timber for fuel, construction, and paper. Currently, up to a quarter of the carbon dioxide emissions to the atmosphere can be attributed to land-use change (CCIR, 2005).

3.2.2.3 Sulfate Aerosols and Black Carbon

Also reported by CCIR (2005), as factors of climate change are sulfate aerosols and black carbon, anthropogenic forces. In their opinion, sulfate aerosols which enter the atmosphere which they stipulated as two important additional examples of naturally during volcanic eruptions, are tiny airborne particles that reflect sunlight back to space. Industrial activity has recently increased their concentration in the atmosphere primarily through the burning of fossil fuels containing sulfur. Anthropogenic emissions of sulfate aerosols have been associated with a net cooling effect. Black carbon is soot generated from industrial pollution, traffic, outdoor fires, and the burning of coal and biomass fuels. Black carbon is formed by incomplete combustion especially of coal, diesel fuels, biofuels and outdoor biomass burning. Soot particles absorb sunlight, both heating the air and reducing the amount of sunlight reaching the ground.

3.2.2.4 Population Growth

CCIR (2005), has it that over the past century changes in concentrations of greenhouse gases in the atmosphere are of an unprecedented rate and magnitude. Human population growth has led to increasing demands for energy and land resources. Through the burning of fossil fuels to produce energy for industrial use, transportation, and domestic power, and through land-use change for agriculture and forest products, humans have been altering the Earth’s energy balance. Scientists believe that these changes may have already begun to alter the global climate.

3.3 Effects of Climate Change

3.3.1 Effects of Climate Change on Building Design

Claudia (2004), opined that weather related impacts: flooding, coastal erosion, subsidence, drainage systems require new building techniques and materials to withstand adverse weather conditions; influences the choice of site, cost of finance/insurance: in a case where Insurance sector is beginning to factor impacts of climate change into premiums. Sector has yet to put systems into place to discount climate-change related risk mitigation, but could be pushed to do so through building industry initiatives.

Kimmo (2005), in his contribution to the ECONO project report opined that climatic factors affect buildings. According to him the intensity and direction of the wind affects the walls, roofs and groups of building. In his review he cited Alberts who was of the opinion that "the effects of the wind in closed blocks and the street spaces between them depend essentially on their total dimensioning" as buttressed in the following:

1. The closed block structure brings special flows, which are the total result of many simultaneously affecting powers. These are the vertical wind whirl which starts from the outer corner of the block and a large whirl, which is created in the street space and which begins from the lee on a level with the eaves line of the building and continues as a large whirlwind which is directed at the facade of the opposite building. These currents are created most easily in a town structure, which is located at an angle of 30–60 degrees to the dominating wind direction.

2. In a closed block, where the width of the yard is about 60 m and in which the buildings are less than 12 m high, the wind continues over the block to the street space. If the same block is built over 12 meters high, the air will stay in the block as a whirl current.

3. In a street space, whose width is more than 30 m, a horizontal whirl which develops from the flows around the buildings is created. If the street space is narrower, the horizontal whirl will not be created.

4. In a broad street space the largest current will be created, when the direction of the wind is parallel with the street. In narrow streets the wind that blows at an angle of 45 degrees with respect to the street network causes the highest flow rate.

5. A massive building causes more windiness in its immediate surroundings, than a building mass as big, which is divided properly.

6. The longest uniform street canyons are also the windiest" (Alberts).

Wilby (2007), reviewed on climate change impacts on the built environment, he collated evidence of effects in four main areas: urban ventilation and cooling, urban drainage and flood risk, water resources, and outdoor spaces (including air quality and biodiversity). He found that built areas exert considerable influence over their local climate and environment, and that urban populations are already facing a range of weather-related risks such as heat waves, air pollution episodes and flooding. According to him, though climate change is expected to compound these problems, building designers and spatial planners are responding through improved building design and layout of cities. For example, green roofs and spaces provide multiple benefits for air quality, mitigating excessive heat and enhancing biodiversity.

Hallegate (2009), in her study on strategies of adaptation to climate change also noted that uncertainty in future climate makes it impossible to directly use the output of a single climate model as an input for infrastructure design, and there are good reasons to think that the needed climate information will not be available soon. Instead of optimizing based on the climate conditions projected by models, therefore, future infrastructure should be made more robust to possible changes in climate conditions.

In CCINW (2010), it was noted that varying impacts of climate change should be taken into considerations while planning, refurbishing or designing a building. Changes like higher winter, urban heat which reduces air quality, drought caused by dessert encroachment, also reduced soil moisture content/ increased subsidence which often leads to cracks in buildings that further develop into advanced failure. Increased river flooding which Increases urban drainage flooding and has severe health implications. The knowledge of all these will help to factor them into design, thereby prepared for their impact. Therefore the necessary professional to put this in place must be present at the design stage. The key challenge is to plan, design and construct cities, neighborhoods and buildings, in accordance with the principles of sustainable development, that perform effectively not just in terms of today's climate but in the future as well invariably creating a friendly environment**.**

USAID (2012), in their Fact sheet report titled Addressing climate change impact on infrastructure; preparing for change, stated that, buildings are typically designed for a specific climate and are constructed to last for decades. However, climate change will alter current conditions, challenging buildings to operate under a wider range of climatic conditions that may push the boundaries of current design standards. A number of climatic changes such as temperature, precipitation, sea level rise, and extreme events, will affect building infrastructure and operations. An extreme event, for example, may cause deterioration or damage to the interior or exterior of a building, and the equipment located within these buildings. Alternatively, intense precipitation may cause flooding or washing out of poorly constructed or situated settlements.

Climate design includes building coordination with its surrounding natural environment and utilization of natural resources located in the way that they made suitable environment for users (Zare'ian, Saniee, DelfanAzari, Aligholi, 2014). They further stated that climate design refers to methods that its aim is to reduce costs of building heat and cold by using natural flows for making comfort in buildings. In all kind of weather, buildings which are built according to principles of climate design, reduce necessity of cooling and heating of mechanical building as minimum as possible and instead they use natural energy located in surrounding of building. In their Paper on "Analysis of climatic factors influencing the architecture in the city of Darab" (Zare'ian 2014 *et al*) they noted that one of the important issues in discussion of building and habitable environment architecture consistent with climate is issue of warming them in cold season and cooling them in warm periods of year for reaching the range of warm human comfort. So by presenting special arrangements related to shape, window dimensions, construction materials and climate condition, we can provide maximum thrift for heat and cold of habitable environments, we should notice that building design is incomplete based on heating in winter season and if shedding is not considered for summer, this kind of design is also harmful.

Patrick (2014), in his paper on climate change; implications for building, reported that Buildings face major risks of damage from the projected impacts of climate change, having already experienced a big increase in extreme weather damage in recent decades. According to him, there is likely to be significant regional variation in the intensity and nature of such impacts. He recommended that radical change within the building sector requires aggressive and sustained policies and actions across the design, construction, and operation of buildings and their equipment, and will benefit from market and policy incentives. Advances in technologies, know-how and policy provide opportunities to stabilize or reduce energy use from buildings by mid-century. Recent large improvements in performance and costs make very low energy construction and retrofits economically attractive, sometimes even at net negative costs.

Scott, Lee, Member And Doug (2014), examined the impacts of future climate variability on the energy consumption, peak energy demand and energy costs at NASA's John C. Stennis Space Center (SSC) in southern Mississippi and in addition, looked at adaptation strategies to mitigate the effects of climate change on building energy performance. They applied field survey method with measurements taken from the NASA's John C. Stennis Space Center (SSC). They found that most of the projected energy impacts under the low impact scenario are moderate and do not present a great risk to facilities operations over a times pan of decades. These impacts are moderate due to small projected changes in climate at SSC and by the large percentage of climate-independent energy consumption. Both high and low impact scenarios project increases in natural gas consumption and peak heating demand. From an SSC facilities standpoint, care should be taken in applying traditional methods in the design of heating systems, as results indicate increased capacity may be needed in the future. Or, alternately, care should be taken to decrease heating loads through energy efficient design and retrofit.

Ijioma (2018) in his report on "the challenges of fickle and inconsistent climate stated that it is certain that climate change has shaped man's history and bears great influence on our everyday affairs which involves the design of buildings and the shape of cities, much more reflects man's dominion over the environment. The report also suggested actions that can help manage the environment against climate change which includes avoidance of bush burning, burning less of fuel wood, reduction of the rate of electricity used. The report recommended that government should step in and put up legislations prohibiting certain actions that bring about increase of greenhouse gases in the air.

3.3.2 Effects of Climate Change on Building Cost

Ackerman and Stanton (2008), in their review on the cost of climate change noted that global warming comes with a big price tag for every country around the world. The 80 percent reduction in U.S. emissions that will be needed to lead international action to stop climate change may not come cheaply, but the cost of failing to act will be much greater. New research shows that if present trends continue, the total cost of global warming will be as high as 3.6 percent of gross domestic product (GDP). Four global warming impacts alone: hurricane damage, real estate losses, energy costs, and water costs; will come with a price tag of 1.8 percent of U.S. GDP, or almost $1.9 trillion annually (in today's dollars) by 2100.

Ackerman and Stanton (2008), in their report, noted that it is difficult to put a price tag on many of the costs of climate change: loss of human lives and health, species extinction, loss of unique ecosystems, increased social conflict, and other impacts extend far beyond any monetary measure. But by measuring the economic damage of global warming in the United States, we can begin to understand the magnitude of the challenges we will face if we continue to do nothing to push back against climate change. Curbing global warming pollution will require a substantial investment, they also noted that the cost of doing nothing will be far greater. Immediate action can save lives, avoid trillions of dollars of economic damage, and put us on a path to solving one of the greatest challenges of the 21st century.

Hallegatte (2009), in her study on strategies to adapt to uncertain climate change, opined that new infrastructure will have to be able to cope with a large range of changing climate conditions, which will make design more difficult and construction more expensive. According to her, it is essential to consider both negative and positive side-effects and externalities of adaptation measures as the cost implication is unavoidable. She also recommended that adaptation–mitigation interactions need integrated design and assessment of adaptation and mitigation policies, which are often developed by distinct communities.

Patrick (2014) in his contribution to the fifth assessment report of the IPCC found that impacts of climate change such as heat stress, extreme precipitation, inland and coastal flooding, landslides, air pollution, drought, and water scarcity pose risks in urban areas that are amplified by a lack of essential infrastructure and services or by living in poor-quality housing and exposed areas.

Improving housing and resilient infrastructure systems could significantly reduce vulnerability and exposure in urban areas.

The socio-economic and environmental importance of buildings cannot be over emphasized as it is an indispensable factor of development. According to the USAID Fact sheet (2012), buildings act as a hub for activities that support sustained and equitable economic and social development at all scales. For instance; public buildings provide the infrastructure and operations needed to support democracy and supply essential services, such as education, health, public policy, and civil protection.

Since 1970s the effects of climate change has been so clear, and worsened by decades. It affects all sectors, buildings inclusive. Okolie, (2011) noted in his study on “Performance Evaluation of Buildings in Educational Institutions, in South-East Nigeria” that buildings can be effective and exciting places to work, use and live in and this can only be acceptable when they encourage adaptability, improve comfort, support a sense of community and provide connections to the natural environment, natural light and view.

In the fifth assessment report of the IPCC (2001), “Working Group I Third Assessment Report” highlighted that buildings face multiple climate change impacts. According to the report, the impacts are on building design, building materials, energy use, cost and the maintenance. These impacts come as a result of the following: frequent strong wind, increased heat, floods, wildfires that accompany some extreme weather events, particularly in cities.

Patrick, (2014) also pointed that building have already experienced big increases in damage over recent decades. This climate variability and change has intensified and is expected to worsen in future. This is expected to affect important natural resources, agriculture and human settlements. This will in turn affect the livelihoods of all those who depend on them, necessitating response through adaptation and mitigation measures that will enable the individuals to cope with the impacts of climate variability and change. The effects of climate change in relation with building structures in Nigeria was heavily felt in 2012 during the notable flooding, owing to the fact that Nigeria doesn’t have the necessary facilities to handle these effects. However, it is not very clear to what extent the building industry are adapted or has put up measures for mitigation. This alone is dangerous and then, the urgent need to have adequate knowledge on measures that can enhance resilience to the expected change and variability.

USAID Fact Sheet (2012), also noted that high temperatures and heat waves will cause internal building temperatures to increase, particularly when combined with the urban heat island effect in cities. This may result in heat stress, health problems, and loss of productivity for those who inhabit the buildings. According to USAID, More humid weather will affect buildings in warm weather climates, with the effect being glaring for instance, Sea level rise could permanently inundate homes, workplaces, or service centers. Flooded coastal health centers could hamper delivery of critical health services amongst many other effects. These effects have their economic implications especially with respect to cost of maintenance of the affected buildings, cost of rehabilitation and reconstruction of these buildings and the change in design of future buildings to accommodate the impact of these changes in the climate element.

According to Scott *et al* (2014), in their examination of the adaptation strategies to mitigate the effects of climate change on building energy performance, increasing roof insulation, upgrading to more efficient cooling equipment, and using energy recovery ventilation were particularly effective for SSC. Thus, continuing to apply standard energy efficiency technologies to existing buildings and new construction, while already required for meeting federal energy reduction mandates, will also lessen the impacts from projected climate variability. Summarily, they identified four secondary strategies. The first three strategies—increasing wall insulation, installing high performance windows, and sealing air leaks—indirectly reduce energy use by isolating the conditioned indoor environment from the outdoor climate all of which have cost implications. The fourth strategy—upgrading to condensing boilers—directly reduces the amount of heating energy needed to offset the increased need for heating during the colder winters.

3.3.3 Effects of Climate Change on Building Materials.

Claudia (2004), pointed out that the cement sector alone is responsible for 5% of anthropogenic CO_2 emissions. He also noted that mining/manufacture of materials and chemicals has significant impact on climate change as well as transportation of heavy materials like cement is energy-intensive, chemical processes , maintenance of buildings and the use of fuel and electricity; highly affects climate change. Critically considering this, one may actually see the extraction and management of building materials as a factor of climate change while climate change itself affects the availability and cost of these materials.

According to CCINW (2010), the use of reflective materials on the external surfaces of buildings or in hard landscaping to lessen the impact of climate change is based on the albedo effect. This is the extent to which a material reflects light, e.g. from the sun, with a range of possible values from 0 (dark) to 1 (bright). Replacing dark roofs and pavements with lighter-coloured ones increases urban albedo. Most existing flat roofs are dark and reflect only 10 to 20% of the sunlight falling on them. Such roofs can be replaced with a lighter-coloured material capable of reflecting 40% or more of the incoming sunlight so reducing heat gain by the building fabric.

The materials used for the structure of buildings and for their internal surfaces are also important because of the effect of thermal mass. The thermal behavior of a material depends on its density, thermal conductivity and specific heat capacity. A high thermal mass is capable of absorbing, storing and slowly releasing heat. Traditional forms of building where thermal mass is integrated with natural ventilation, small window openings and deep eaves can keep buildings cool in hot climates.

According to USAID (2012), climate change risks vary in relative importance, with a range of cost implications, compounding effects, and impacts on development objectives. By damaging facilities or disrupting activities, climate change impacts on buildings can have far-reaching implications for safety, economic growth, poverty reduction, and other development objectives. For example, a loss of industrial agriculture processing capability could affect food markets by reducing access and increasing prices as the impact on the buildings increases, the need to replace the existing structures or constructing new ones with more resilient materials sets in. These effects, in turn, will likely have disproportionate impacts on the most impoverished populations.

3.3.4 Effects of Climate Change on Building Maintenance.

Scott *et al* (2014), while examining the impacts of future climate variability on the energy consumption, peak energy demand and energy costs at NASA's John C. Stennis Space Center (SSC) in southern Mississippi also found that the high impact scenario projects potentially disruptive increases in cooling peak demand and resulting peak electric demand. This is due to sizable projected increases in both peak dry-bulb and wet-bulb temperatures. Thermal storage technologies may offer increased value by providing methods to ride-through longer and more frequent peak demand events, which is higher cost of management and maintenance. Specifying larger capacities for these systems, in particular for campus distribution systems, should be considered during upgrades and new construction (when smaller incremental costs are incurred).

3.3.5 Effects of Climate Change on Building Energy Needs

Frank (2005), investigated the potential impacts of climate change on heating and cooling energy demand were investigated by means of transient building energy simulations and hourly weather data scenarios for the Zurich–Kloten location, which is representative for the climatic situation in the Swiss Central Plateau. A multistory building with varying thermal insulation levels and internal heat gains, and a fixed window area fraction of 30% was considered. For the time horizon 2050–2100, a climatic warm reference year scenario was used that foresees a 4.4 °C rise in mean annual air temperature relative to the 1961–1990 climatological normal ranges and is thereby roughly in line with the climate change predictions made by the Intergovernmental Panel on Climate Change (IPCC). The calculation results show a 33–44% decrease in the annual heating energy demand for Swiss residential buildings for the period 2050–2100. The annual cooling energy demand for office buildings with internal heat gains of 20–30 W/m^2 will increase by 223–1050% while the heating energy demand will fall by 36–58%. A shortening of the heating season by up to 53 days can be observed. The study found that efficient solar protection and night ventilation strategies capable of keeping indoor air temperatures within an acceptable comfort range and obviating the need for cooling plant are set to become a crucial building design issue.

Christenson, Manz and Gyalistras (2006), investigated the impact of climate warming on Swiss building energy demand by means of the degree-days method. A procedure to estimate heating degree-days (HDD) and cooling degree-days (CDD) from monthly temperature data was developed, tested and applied to four representative Swiss locations. Past trends were determined from homogenized temperature data for the period 1901–2003. The range of possible future trends for the 21st century was assessed based on 41 regional climate change scenarios derived from 35 simulations with 8 global climate models. During 1901–2003, the HDD were found to have decreased by 11–18%, depending on the threshold temperature (8, 10 or 12 °C) and location. For the period 1975–2085, the scenario calculations suggested a further decrease between 13% and 87%. For CDD, accelerating positive trends were found during the 20th and 21st centuries. The

HDD showed the largest absolute and the CDD the largest relative sensitivity to warming (albeit starting from relatively low levels). According to them, weather data currently used for building design increasingly lead to an overestimation of heating and underestimation of cooling demand in buildings and, thus, require periodic adaptation. Projections were particularly sensitive to the choice of temperature scenario and they suggested that for the next decade's significant, seasonally and regionally variable shifts in the energy consumption of Swiss buildings needs to be studied and properly accommodated by the future designs for buildings.

Ackerman and Stanton (2008), also stated that temperature rise, regional variations in precipitation and humidity are important determinants of local climates. Hot temperatures combined with high humidity levels are often more unpleasant, and worse for human health, than a hot but dry climate. In addition, perceived heat of each local climate will be determined by annual average temperatures, temperature extremes, heat waves and cold snaps and precipitation levels, as well as some ecosystem effects. They assumed that in the business as usual case, heat waves will become more frequent and more intense. Changes in precipitation patterns are likely to differ for each region of the United States and all of these have implications with respect to energy need in already existing infrastructures and future ones.

Kevin, Danny, Wenyan and Joseph (2011), investigated the impact of climate change on energy use in office buildings in a city within each of the five major architectural climates across China: Harbin (severe cold), Beijing (cold), Shanghai (hot summer and cold winter), Kunming (mild) and Hong Kong (hot summer and warm winter); were investigated for two emission scenarios. For low forcing, the estimated increase in cooling energy use was 18.5% in Harbin, 20.4% in Beijing, 11.4% in Shanghai, 24.2% in Kunming and 14.1% in Hong Kong; and the reduction in heating 22.3% in Harbin, 26.6% in Beijing, 55.7% in Shanghai, 13.8% in Kunming and 23.6% in Hong Kong. Space heating is usually provided by oil- or gas-fired boiler plants, whereas space cooling mainly relies on electricity. In their findings, there would certainly be a shift towards electrical power demand. More energy use in buildings would lead to larger emissions, which in turn would exacerbate climate change and global warming. Energy conservation measures were considered to mitigate the impact of climate change on building energy use. These included building envelope, indoor condition, lightening load density and chiller coefficient of performance. It was found that raising the summer indoor design condition by 1–2 °C could result in significant energy savings and have great mitigation potential.

3.3.6 Adaptation to Climate Change in Building Construction

According to CCI NW (2010), in their report on ‘’adapting to the impact of climate change on buildings neighborhoods and cities’’ they opined that within the built environment sector, climate change adaptation is often used simply to mean changes that can be made to the design or construction (less often the operation or use) of buildings and landscaping in order to cope with the consequences of one or more of the impacts of climate change. They also noted that adaptation is steps taken to reduce the effects and take advantage of the opportunity of existing climate change and the expected.

Possible adaptation to climate change includes

1. Employ building shape and orientation to provide solar control
2. Employ cool or reflective building materials on roofs and facades use green or brown roofs and green walls to regulate temperature
3. Provide external solar shading install (controllable, secure) natural (night time) ventilation, integrated with security
4. Increase thermal capacity of construction
5. Increase insulation and air tightness of building envelope reduce internal heat gains through correct location and
6. Use of energy efficient appliances and lighting
7. Use ground water source heat exchange for cooling (heating) where mechanical air handling units installed, ensure don’t discharge into frequented external spaces allow for appropriate in-house storage of composting, waste and recycling in hot weather
8. Plan for long term management and maintenance of adaptation measures
9. Monitor and evaluate performance (internal conditions and external spaces)

If nothing is done, the consequences of climate change will be much; ranging from flood to coastal erosion, water shortages, ground instability and temperature increase. This is detrimental to building maintenance as increased temperature raises more demand on energy use as well as the infrastructure.

Ackerman *et al* (2008), in their report, pointed that building seawall in order to hold back rising water is a good adaptive measure but the question is, how many countries have enough resources to practice this. There are a number of ecological costs associated with building walls to hold back the sea, including accelerated beach erosion; disruption of nesting and breeding grounds for important species, such as sea turtles; and prevention of the migration of displaced wetland species. In order to prevent flooding in developed areas, some parts of the coast would require the installation of new seawalls. Estimates for building or retrofitting seawalls range from $2 million to $20 million per linear mile. There is no single, believable technology or strategy for protecting vulnerable areas throughout the country. The high cost of adapting to sea-level rise underscores the need to act early to prevent the worst impacts of global warming.

Malay, Arvind and Peter (2012), in their review on assessing the climate change adaptability of buildings pointed out that buildings present a significant amount of opportunity for climate mitigation. Considering the fact that they are long-lived assets, they also pose great challenges for adaptation to projected as well as unexpected climate change impacts. These impacts will have consequences for building design and fabric, as well as for people in and around buildings and for their health and well-being. It is essential that we identify the nature and extent of their vulnerabilities and resilience if they are to be adapted in a timely and effective manner.

Malay, *et al* (2012), also noted that designing for adaptability provides a framework for making strategic decisions about the right mix of flexibility and durability in buildings. A building that is designed for adaptability, according to this approach, would be designed:

1. With the end of the building life in mind.

2. Considering it as a system of temporal layers and designed for accommodating the changes the building and its components would undergo during the entire lifecycle.

3. For long-life; or for long term durability and sustainability of building and durable amenity for its occupants.

4. For loose-fit; or for spatial flexibility, structural flexibility, flexibility to assist materials and components change.

5. For deconstruction; or for independence between different layers or components with different functions to aid in disassembling for reuse, recycling or replacement.

According to Malay *et al* (2012), lack of consistent, up to date and appropriate information and knowledge is often cited as one of the barriers to effective adaptation. This is well-reflected in the confusion that surrounds the use of different terminologies related to and different notions of adaptability in buildings. With a wide range in focus and preference, these various concepts and definitions seem to offer insights into what would be the characteristics of a climate-adaptable building.

There is also lack of a clear and well-accepted definition for climate-adaptable buildings distinct from other often interchangeably used terms such as climate resilient buildings. Whilst there are assessment tools and methods used for identifying vulnerability and adaptive capacity of various systems from planning to urban governance, there appears to be a knowledge and policy gap in the area of assessment of existing and new buildings to identify and quantify their vulnerability to climate impacts. It is essential that there is clarity and consistency in the way in which the buildings' climate adaptability and resilience, or the lack thereof, are measured and assessed. There is a pressing need for further research to develop common metric and consistent methodologies of assessment of how adaptable and resilient our existing and new buildings are to projected and unexpected climate impacts. There are also implications of the various priorities for adaptation on assessment criteria for buildings that need to be identified if we are to develop appropriate, timely and effective design and policy measures for adaptation. It is to be noted that currently there are no common legislative or strategic planning frameworks in place to guide climate adaptation responses at either a national or international level. There are also no currently accepted standards for measurement metrics, normalized approaches or indicator sets for the development or comparison of assessment methods or climate adaptation tools. Development of a national level building adaptability and resilience assessment system that can be used for both existing and new buildings by policymakers, regulatory authorities, property insurers, building design and construction industry professionals as well as householders could be highly beneficial.

The research also found gaps between knowledge and practice of adaptation and mitigation. There also appears to be confusion around the interface and synergies between adaptation and mitigation strategies. There is a need for improved skills and preparedness of building professionals to advise, encourage and implement adaptation measures. There are considerable opportunities in linking adaptation with mitigation so that the climate resilience measures become integrated in the GHG emission reduction agendas for all types of buildings. This will lead to both low-carbon and climate resilient buildings and cities.

3.4 Summary of Literature

Climate change is a contemporary issue, which has attained global concern and has continually sought global commitment for its control. This universal issue which has its root on both natural and anthropogenic causes has no single solution or modalities to contain it. It, therefore, becomes a problem of which scientist and researchers from various backgrounds are pressing to solve. Considering that its impacts are not limited to only specific discipline or economic sector, the search for its solution or control measures thus becomes a multi-disciplinary affair with every discipline seeing it from its own perceptive, and suggesting solutions from its own point of view, as seen in the above review. It has been proven by the works of Claudia, (2004); Scot *et al* 2014, among others that climate change affects building design.

In an assessment done by Christenson *et al*, (2006), it was noted that climate change has effects on the building energy needs and Malay *et al*, (2012) also pointed out the issues of adaptation of the industry to climate change effects. Although series of works have been done mostly in the western world and developed nations about building design and energy need with respect to climate parameters but most developing nations like Nigeria and some other West African countries are still at the beginning of this advancement trend. Works have been done in many nations like the works of UNEP, (2007) where it was noted that building and construction sector typically provides 5-10% of employment at national level and normally generates 5-15% of the GDP, this shows the importance of building to the society but such empirical work is yet to find a feet in Nigeria.

Considering that climate change is a continuous event which has started from the existence of man on earth and extending to an unknown period. It calls for a continuous research from different works of life to address this issue. Building design has changed over time with technological advancement as new technologists emerge, new building designs also emerge. One can recall that in the 50s, the type of building structures we had in the eastern part of Nigeria is very different from what we have today.

But, with civilization, economic and technological advancement, new building structures with more environmentally compliant designs are also being constructed. It should be noted that for every technological advancement program or project invention, innovation or refurbishment, there is a problem at the center or an issue that is being settled be it environmental, social, economic or otherwise. It is true that the change in building design is a product of technological advancement but it should be noted that this technological advancement is aimed at solving problem. The new building designs has their ventilation, roofing, foundation, design and developed to accommodate the environmental conditions prevalent in an area in some parts of China, buildings are being constructed with woods while scaffolds are being made of bamboos even up to the level of sky scrapers, this is because it is more economical and environmentally.

In some parts of Japan, heavy concrete construction is used for building but as the environmental hazard of earthquake increases, they started building with light wood and fiber materials. Such as after every earthquake, human beings will immediately remove the fiber materials and come out unlike the heavy concrete construction. This goes to say that all the professionals in the built environment must adopt more compliant designs and materials which are cost effective.

The USAID (2012), recommended that Development practitioners can employ a range of adaptation actions that reduce the vulnerability of building infrastructure and operations to climate change impacts. Actions include operational and policy changes such as increases in maintenance activities, development of risk management protocols, or support of flexible dress requirements that allow for climate appropriate attire. Other options are structural changes such as alterations in building and equipment materials, moving electrical infrastructure above flood levels, or use of deeper foundations. Some adaptation strategies, particularly changes in building materials and design, are proactive and should be considered in the project design stage. Other adaptation strategies, like renovating exterior landscapes, can be implemented over time and as conditions evolve. It is important to note that their recommendation also advised decision makers to consider the following four key factors as they priorities adaptation measures:

1. Criticality– How important are the buildings for achieving development objectives, such as education, employment, or economic growth? Are the buildings required during emergencies?

2. Likelihood– Given climate scenarios, are the buildings likely to be impacted by climate change?

3. Consequences– How severely will the building infrastructure or operations be affected? Will climate change impacts permanently or temporarily disrupt the use of buildings?

   Resources available– Can adaptation measures be incorporated into ongoing maintenance and renovation plans? Are substantial investments required to retain use of the buildings?

3.5 Literature Gaps

After the review of the related works, the following gaps were identified:

1. None of the works did an assessment of the impact of climate change on building design and cost in Nigeria, Enugu State inclusive.

2. None of the works did a time series or trend analysis of the rate of change of climate variables for the past five decades in Enugu Metropolis.

3. None of the research works investigated to establish whether or not the change in building materials is as a result of climate change or normal technological advancement.

4. There were works reviewed under building energy needs variation like the work of Frank (2005), who investigated the potential impacts of climate change on heating and cooling energy demand, but none within the entire part of the south east of Nigeria.

CHAPTER FOUR

4.0 RESEARCH METHODOLOGY

This chapter of the study discusses the research methods adopted in order to arrive at the aim of the study. The steps and approaches applied in achieving the aim of this study were discussed as follows:

4.1 Research Design

Sequel to the aim and objective of this study, the research design adopted was the survey design. This involves the use of well-structured questionnaire for collection of data on their individual views on the effects of climate change on buildings in relation with design, construction cost, material, maintenance and energy, also site investigation/observation and personal interviews with authorities in the field of building and climate change. The questionnaire was specially constructed to get the views of the Builders, Architects, Quantity Surveyors and building owners. According to Kothari (2014), research design involves the arrangement of conditions for collection and analysis of data in a manner that aims to combine relevance to the research purpose with economy in procedure.

4.3 Data Need

For a thorough assessment of the impact of climate change on building, data was obtained for climate variables/elements or parameters from the Nigerian Meteorological Agency (NIMET). This data enabled the establishment of the variation of the climate parameters over the period of time under study. Data was generated from interview and questionnaire from building experts within the study area on variation in building design, building cost, building materials, building energy need within the period of time under study. These data were juxtaposed with the data generated from the variation of the climate parameters in the study area within the study period in determining the level of impact of the change of climate parameters on building design; cost and energy need over the said time.

4.4 Sources of Data

In view of the aim and objectives of the study, data was derived from both primary and secondary sources.

4.4.1 The Primary Data

The primary data was originally sourced by the researcher in line with the description of the research design. The primary data of this study was focused on records of observations and questionnaire responses by respondents and responses from personal interviews and discussions.

4.4.2 Secondary Data

In line with the need to establish a sound background to this study and theoretical/conceptual frame of this study, the study generated data from already existing/related research works and write ups of authorities and early scholars as contained in textbooks, journals, conference proceedings, published and unpublished students dissertations, recorded climatic data over the study years and media reports among others.

4.5 Methods of Data Collection

The data for this research work was collected using the following methods:

4.5.1 Field Observations

Here a reconnaissance survey and subsequent field inspection was conducted in the study area, data on the prevalent types of building, prevalent building design and recent approaches to building resilient houses were collected.

4.5.2 Personal Interview

Interview was personally conducted with the landlords within the study area and the professionals. The essence of this interview is to answer questions like; how long the building has lasted, average cost of maintaining the building, has there being any renovation in recent times, is there variation in heat and energy need of the house over the period time under study. Also, considering the fact that the variation in cost is not only a product of climate change, there is need to ascertain from the owners of the houses and experts on other factors that contributed to the variation in cost over time.

4.5.3 Questionnaire Survey

A well-structured questionnaire was used to collect data from the professionals and building occupants on the impacts of climate change on building designs, materials, construction and maintenance cost and building energy need, the questionnaire was self-administered with the questions both closed and open ended.

4.6 Study Population

The idea of population is to obtain some parts of the population from which some information on the entire population can be inferred. The population for the study comprised of inhabitants of Enugu metropolis. The metropolis covers three local government areas and nine principal district, some of which are Trans-Ekulu, Uwani, Caol Camp (Ogbete), Achara Layout, New Haven, Ogui etc (Ezenwaji, Nzoiwu and Eduputa, 2016). According to NPC (2006), the population of the town was 772,664 in 2006 while its 2016 population was projected to 910, 003 using the growth rate of 3% for urban areas in Nigeria. Household size of six was adopted for the study and this was used to determine the number of household. The number of household was calculated and this showed that there are 151,668 households in Enugu.

4.7 Sampling Size and Techniques

In order to determine the sample size of the study, the total number of households within the study area were reduced to a sample population by the application of Taro Yamane formula.

Below is the Taro Yamane formula used in drawing sample size:

$$n = \frac{N}{1 + N(e^2)}$$

$$n = \frac{910{,}003}{1 + 910{,}003(0.05^2)} = 399.9 \approx 400$$

where: n is the sample size, N is the number of households (population size), e is the estimated error=0.05, 1 is constant.

Purposive non-probability sampling method was used due to the fact that the aspect of the population to be sampled was based on individuals living in Enugu urban. Thus, Builders, Quantity Surveyors, Civil Engineers and Architects in Enugu State as well as other professionals, landowners/landlords and tenants were purposively selected because of their involvement in building industry. A total of 400 respondents as calculated using Taro Yamane formula constituted the sample for the study.

Having calculated the sample size from the study population, the study will adopt the stratified random sampling techniques. The reason for this technique is because we have variation in discipline of the registered professionals to be sampled and also there is variation in knowledge, exposure, interest, carrier amongst the household leaders to be sampled. At least 40% of the sample size will be randomly selected from each of the professional disciplines to be sampled while the remaining percentage will randomly be selected from the rest of the using a sample frame.

4.8 Method of Data Analysis and Presentation.

The data collected from the questionnaire distributed was analyzed using simple percentages and descriptive analytical tool such as tables in analyzing and presenting the result. The data realized from NiMet was analyzed using time series analysis and presented in tables and charts. For the hypotheses test, the lickers scale questions were subjected to a mean calculation to get the cut off point for the responses of each question. Hypothesis was tested using the climate data from NiMet, The hypotheses 2-5 was tested using the t-test, the formula is given below:

4.8.1. One Sample T–Test

The one sample *t*-test is a statistical procedure used to determine whether a sample of observations could have been generated by a process with a specific mean. Suppose oneis interested in determining whether an assembly line produces laptop computers that weigh five pounds. To test this hypothesis, sample of laptop computers from the assembly line can be collected, their weights measured, and then the sample compared with a value of five using a one-sample *t*-test.

$$t = \frac{\bar{x} - \mu}{\sqrt{s^2/n}}$$

4.8.2 Wilcoxon Signed-Rank Test

The Wilcoxon signed-rank test is a non-parametric statistical hypothesis test used to compare two related samples, matched samples, or repeated measurements on a single sample to assess whether their population mean ranks differ (i.e. it is a paired difference test). It can be used as an alternative to the Paired Samples T-Test, for matched pairs, or the *t*-test for dependent samples when the population cannot be assumed to be normally distributed. A Wilcoxon signed-rank test is a nonparametric test that can be used to determine whether two dependent samples were selected from populations having the same distribution.

The formula is given as:

$$z = \frac{T - \frac{n(n+1)}{4}}{\sqrt{\frac{n(n+1)(2n+1)}{24}}}$$

4.8.2 Time Series Analysis

The temporal variations in the data set for rainfall, temperature and relative humidity were investigated using time series analysis. The graphs of values for rainfall, temperature and relative humidity revealed so many fluctuations that the general trend of the individual variables may not be easily determined. A smoothening function was applied to the data sets so that the general trend of the values may be easily determined. A 5-year moving average was used to smoothen or filter the time series and the principle is as follows: given a set of values, Y_1, Y_2, Y_3, Y_4…., a moving average of order N is given by:

$$\frac{Y_1 + Y_2 + ... + Y_N}{N}, \frac{Y_2 + Y_3 + ... + Y_{N+1}}{N}, \frac{Y_3 + Y_4 + ... + Y_{N+2}}{N} \qquad 4.1$$

A trend analysis was carried out to determine the direction of the temparl sequence of climatic parameters in the study area and their rate of change. This was done by calculating the linear regression and correlation coefficient of the climate data sets over time. The linear regression for the variables may be expressed by the equation:

$$Y = a + bX \qquad 4.2$$

Where

$$b = \frac{\Sigma XY - \frac{(\Sigma X)(\Sigma Y)}{N}}{\Sigma X^2 - \frac{(\Sigma X)^2}{N}} \qquad \text{and} \qquad a = Y - (\bar{X}.b) \qquad 4.3$$

The correlation coefficient *r* is given as:

$$r = \frac{\Sigma XY - \frac{(\Sigma X)(\Sigma Y)}{N}}{\left(\Sigma X^2 - \frac{(\Sigma X)^2}{N}\right)\left(\Sigma Y^2 - \frac{(\Sigma Y)^2}{N}\right)} \qquad 4.4$$

Trend line of best fit was fitted into the time series from the derived individual regression models.

4.8.3 Poisson Regression Analysis

Poisson regression is a form of regression analysis used to model count data (i.e. it is a nonlinear regression analysis of the Poisson distribution, where the analysis is highly suitable for use in analyzing discrete data). Poisson regression assumes that the response variable Y, has a Poisson distribution and assumes that the logarithm of its expected value can be modeled by a linear combination of unknown parameters. Poisson regression models are generalized linear models with the logarithm as the link function, and the Poisson distribution function as the probability distribution.

In statistics, the Generalized Linear Model (GLM) is a flexible generalization of ordinary linear regression that allows for response variables that have error distribution models other than a normal distribution. A generalized linear model is made up of a linear predictor

The Poisson Regression Model is given by:

$$\eta_i = \beta_0 + \beta_1 x_{i1} + \cdots + \beta_k x_{ik} i = 0, 1, 2, ... \qquad 4.5$$

Where:

η_i is the no of occurrence(s) being predicted,

β_0 is the intercept,

β_1 is the coefficient of the first variable,

x_{i1} is the first variable,

β_k is the coefficient of k^{th} variable, and

x_{ik} is the k^{th} variable.

4.8.4 Principal Component Analysis

Other major statistical techniques employed were Principal Component Analysis and Correlation Analysis. Correlation analysis was used to examine the relationships between the perceptions of the respondents on effects of climate parameters on building designs, cost of construction and maintenance, material and energy needs. The Principal Component Analysis (PCA) was utilized to collapse the various nine variables indicating the respondents' opinion on effects of climate parameters on building designs, cost of construction and maintenance, material and energy needs. The PCA was used as a result of the severe autocorrelations noticed in the data. The largest amount of variation in the data set is called an 'eigen vector' and is regarded as the first principal component. Furthermore, a 'varimax rotation' is employed for interpretation of the components and eigen values greater than 1.00 are usually extracted and considered for interpretation (Anyadike, 2009). This statistical analysis was performed with the aid of Statistical Package for Social Sciences (SPSS) version 20 running on windows PC (Ezenwaji et al., 2013)

CHAPTER FIVE

5.0 DATA PRESENTATION, ANALYSIS AND RESULTS

This deals with the analysis of the various data collected from the study area. From the questionnaire administered, collected and analyzed, the results obtained provided insight on the effects of climate change on buildings in Enugu metropolis. A total of 400 copies of the questionnaires were distributed to the respondents in different parts of Enugu metropolis which include: Enugu North, Enugu South and Enugu East. At retrieval, a total of 325 copies were completed, representing 81.25% response rate (table 5.1),in addition, interviews were structured and conducted on selected professionals to elicit additional and necessary data and information from the respondents on pertinent issues of climate effects on cost of construction, cost of maintenance, building designs, energy need in building and building materials. The results obtained are presented in the following tables below.

Table 5.1 Population distribution of questionnaires and percentage responses.

Number Administered	Number Returned	Percentage
400	325	81.25

Source: Researcher field survey 2017

The configuration of the respondents cuts across professionals in the building industry, practitioners in the environmental sector and then, the rest of the public. Amongst the respondents, it was evident, that there are more male respondents than females. This is so because in the course of the research, it was observed that lots of the men were willing to fill the questionnaire and more male were found as house owners, best fit tenants and a greater number of them were the professionals in the built environment.

From the result, the total number of sampled males in the study was 181 representing 55.7% of the population of the study while that of females constitute about 144 representing 44.3%. This indicates that there are more of males than females in the study.

In Table 5.2, the age group of the respondents was also shown; out of 100% of the number of respondents, 29.2% of them were between age bracket of 25 – 35 years of age; 30.8% of the respondents were between the ages of 36 and 45years; 23.7% had ages ranging from 46 to 59 years; while about 16.3% of the respondents were in the age group of above 60 years of age. The result presented below also indicate that majority of the respondents are within the productive age group ranging from 18 to 55 years.

On the duration of stay, table 5.2 presents the result of the responses on how long they have lived in the study area. The questionnaire revealed that about 26.8% of the respondents have lived in the area for less than 5years. About 17.5% of the respondents have lived in Enugu between 6 to 10 years; 16.6% have stayed in the study area for 11 to 20 years, 20.6% of the respondents have equally stayed here for a period of 2 to 3 decades i.e. 21 to 30 years while the remaining 18.5% have stayed for more than 30 years. This confirms that information obtained in the study has both current and dated evaluation. Looking at the educational attainment of the respondents, the result indicates that all the respondents have varying levels of formal education. A large number of the respondents (47.4%) indicated that their highest level of education attainment is B.Sc; 14.2% of the respondents noted that they have acquired Masters' Degrees or on the course of achieving that feat while about 7.4% of the respondents have obtained Ph.D. or is still in view. However, a good number of the respondents (31.1%) selected others have attended and completed primary education while none of the respondents reported are without any formal education. Also, it is impressive to know that the respondents had one form of formal education or the other and as such understood the contents of the questionnaire.

Regarding the residential status of the respondents, out of the 325 returned questionnaires, majority of them were shown to be tenants and constitute about 64.6% of the respondents. This was followed by family house occupants or attachment occupants that make up about 22.8% while landlords or house owners take up 12.6%.

The Engineers which cut across civil, mechanical and electrical engineers constitutes about 13.5% of the respondents, Builders make 6.8% while Architects and Quantity Surveyors take up 8.9% and 10.2% respectively. The Other section of the occupation, which constitute the largest percentage of the respondents, is made up of various categories of post graduate students, meteorologists, environmental practitioners and consultants, academics, aviators, public servants etc. This takes up about 60.6% of the total respondents.

Table 5.2: Socio–Demographic Characteristics of the Respondents

Characteristics	Factors	Frequency	Percentage (%)
SEX	Male	181	55.7%
	Female	144	44.3%
	Total	**325**	**100.0%**
AGE	25 – 35	95	29.2%
	36 – 45	100	30.8%
	46 – 59	77	27.7%
	60 and above	53	16.3%
	Total	**325**	**100.0%**
DURATION OF STAY	0-5years	87	26.8%
	6-10 years	57	17.5%
	11-15 years	54	16.6%
	16-20 years	67	20.6%
	21 years and above	60	18.5%
	Total	**325**	**100.0%**
RESIDENT STATUS	House owners/ Landlords	41	12.6%
	Tenants	210	64.6%
	Family House Occupants or Attachment	74	22.8%
	Total	**325**	**100%**
EDUCATIONAL QUALIFICATION	HND	0	0.0%
	B.Sc.	154	47.4%
	M.Sc.	46	14.2%
	PhD	24	7.4%
	Others	101	31.1%
	Total	**325**	**100.0%**
OCCUPATION	Engineers	44	13.5%
	Builders	18	6.8%
	Architect	29	8.9%
	Quantity Surveyors	33	10.2%
	Others	197	60.6%
	Total	**325**	**100.0%**

***Source**: Field Survey, 2017*

However, on the nature of climate variability, climate being a phenomenon that cuts across all facets of life, the perception of the respondents were sought to ascertain their level of awareness and their understanding regarding the potential impacts of this phenomenon and its changing parameters on the building industry. First, analysis of the secondary data obtained from NIMET on climate parameters to establish if there are evidences of climate variability and change followed by the results of the interview and questionnaire surveys administered to the respondents were presented and analyzed.

Objective One: To examine variation in climate parameters for five decades (from 1957-2017) within the study area.

This objective was able to examine the variation noticed in the climate parameters from 1957 to 2016. The results are presented in figures 5.1 to 5.8 and they are discussed.

Temperature data for a period of 47 years between 1970 and 2016 was analyzed and presented in fig 5.1. This graph of temperature illustrates the amount of fluctuations in the annual mean temperatures of the study area for the period under study. Least square regression was used in the analysis.

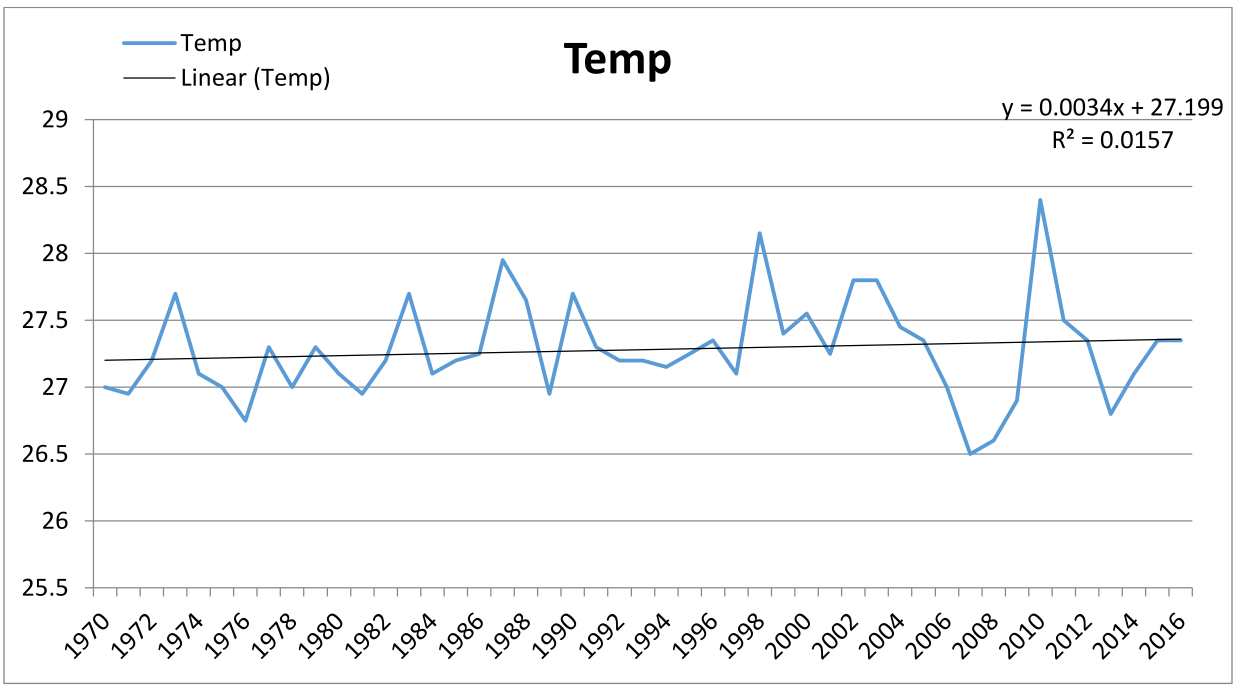

Fig 5.1: Trend plot of temperature variations between 1970 and 2016

The fluctuations in the value of temperature in the study area is of such that, in order to easily determine the general trend of these values, a 5 year moving average was applied to smoothen these fluctuations (fig 5.2). The general direction of the time series for the 47 year period was determined. While it could be seen that the trend is rising (positive), the correlation coefficient, r = 0.122, was found not to be statistically significant.

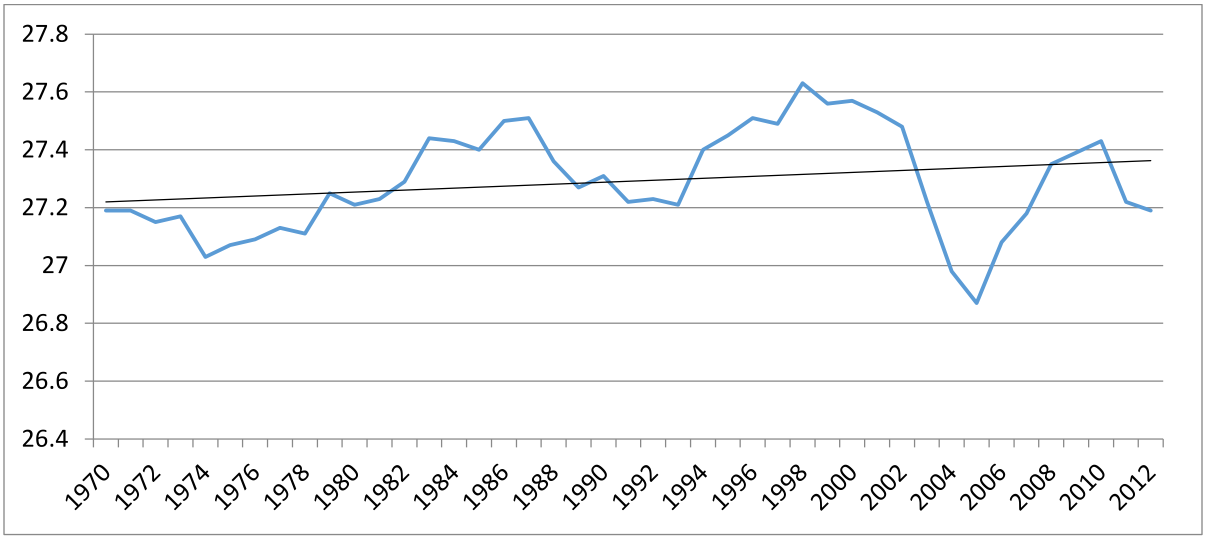

Fig 5.2: Moving average plot of temperature of the study area

From Fig 5.3, showing the temperature anomaly of Enugu, it appears that in support of the results shown, temperature is truly increasing. The overall mean temperature for the 46 year period was calculated to be 27.3^{o}C. From 1970 to 1997, majority of the years have temperature values below the mean while in the past two decades most of the years have shown temperatures above the mean temperature for the period.

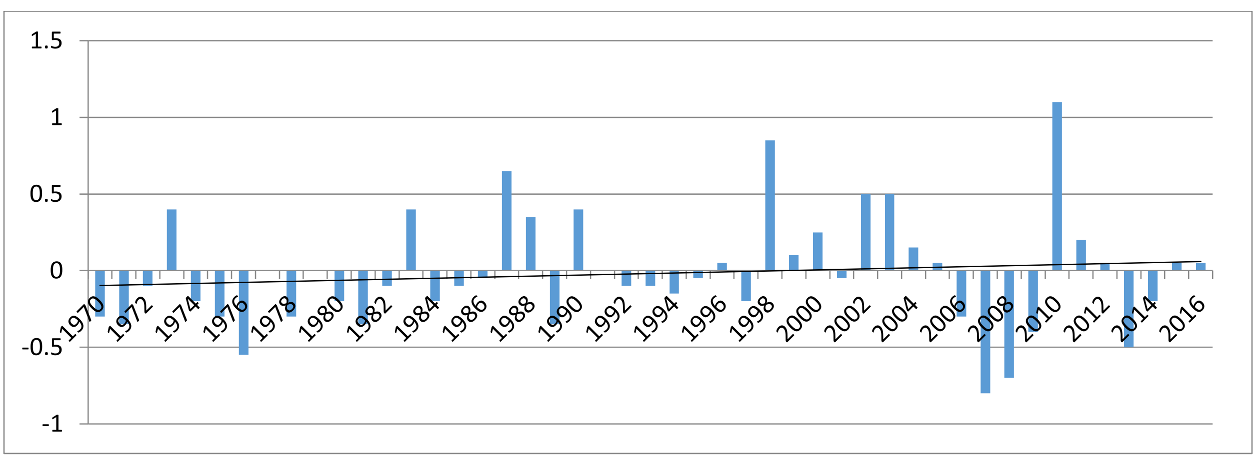

Fig 5.3: Temperature anomaly in Enugu using 1970–2016 normal

However, temperature is generally on the increase in the study area and this appears to be in agreement with the study by Odjugo (2010a) where it was reiterated that temperature trend in Nigeria has shown increasing pattern; that since 1970s, there has been a sharp rise in air temperature which continued until 2005. Prior to 1970s, temperature increase was more gradual and this was also emphasized in Ayoade (2003). Although the temperature increase within the study period is statistically the same, the upward trend especially since the 1970s is a worrisome evidence of regional warming (Odjugo, 2010). Similarly, the observed worrisome trend was clearly depicted in the graph of temporal distribution of minimum temperature characteristics of Enugu.

As shown in fig 5.4, the minimum temperature pattern in Enugu shows a steady increase in mean minimum temperature value for individual years within the 47 year period.

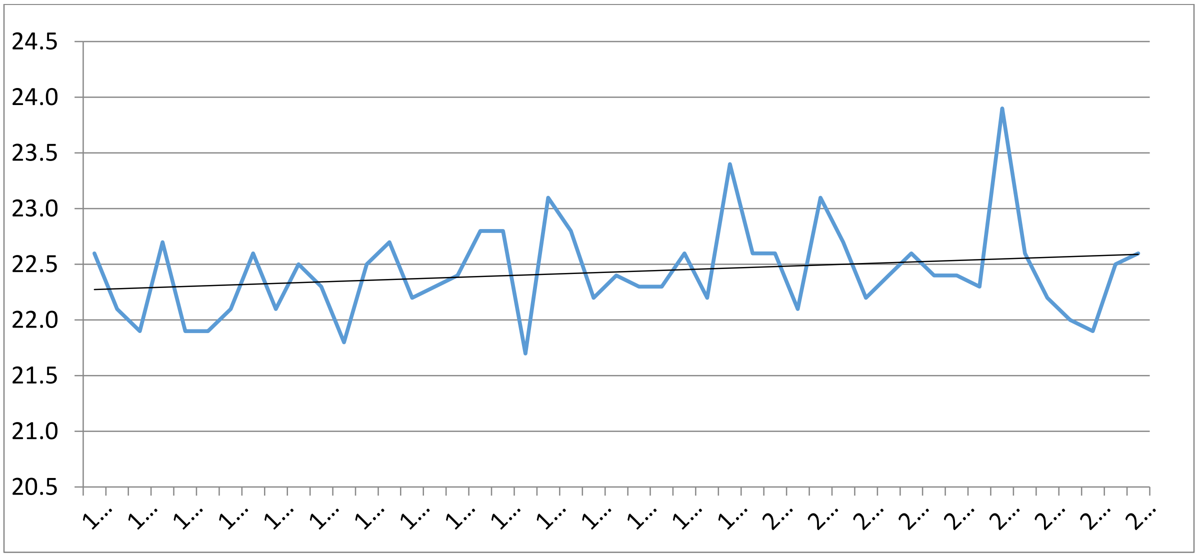

Fig 5.4: Trend plot of minimum temperature variations between 1970 and 2016

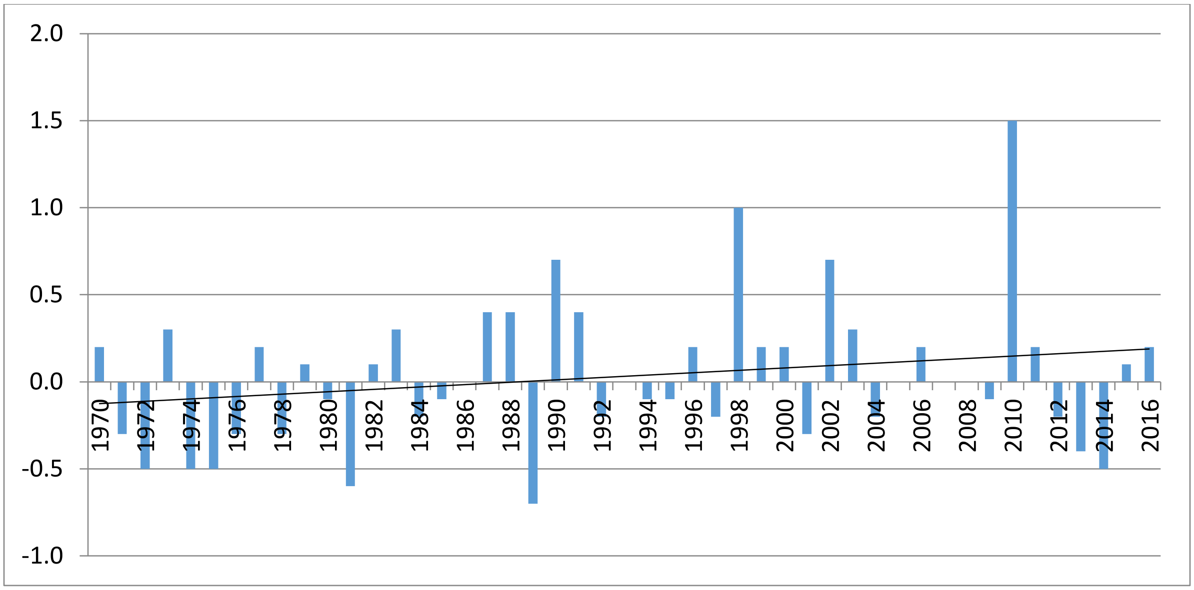

Fig 5.5: Minimum temperature anomaly in Enugu using 1970 – 2016 normal

The observed increase in minimum temperature conditions in Enugu is quite a worrisome trend. This increase was evident from 1990 and has continued till date. The implication of this is that the temperature range in Enugu, that is, the difference between the maximum and minimum temperatures is gravely reducing and this has a wide range of physiological implications. This is equally a confirmation of the fact that Enugu is becoming a heat island as have been variously reported by numerous studies such as Enete (2015).

The mean maximum and minimum temperatures in Enugu for the climatic period, 1970 – 2016, are 32.1^{o}C and 22.4^{o}C respectively with a temperature range of 9.7^{o}C. Within this period, the minimum temperature characteristics of Enugu has witnessed an increase from a minimum of 21.7^{o}C to the highest of 23.9^{o}C while the maximum temperature characteristics has seen a variation from the lowest of 30.6 to the highest of 33.1^{o}C. For further emphasis, the temperature range between the highest minimum temperature of 23.9^{o}C and the highest maximum temperature of 33.1^{o}C recorded in this period is shown to be 9.2^{o}C depicting a range reduction of 0.5^{0}C. Thus, the physiological range in Enugu, if this scenario remains, could be devastating on the long run as the gap is reducing.

Rainfall data for Enugu was obtained from the records of the NiMet. The data were summed anually to generate annual time series of rainfall from 1970 to 2016. The trend plot of rainfall achieved is shown in fig 5.6, indicating that the movement of the time series is sporadic. The least square method was used to determine the trend in the time series of rainfall shown below.

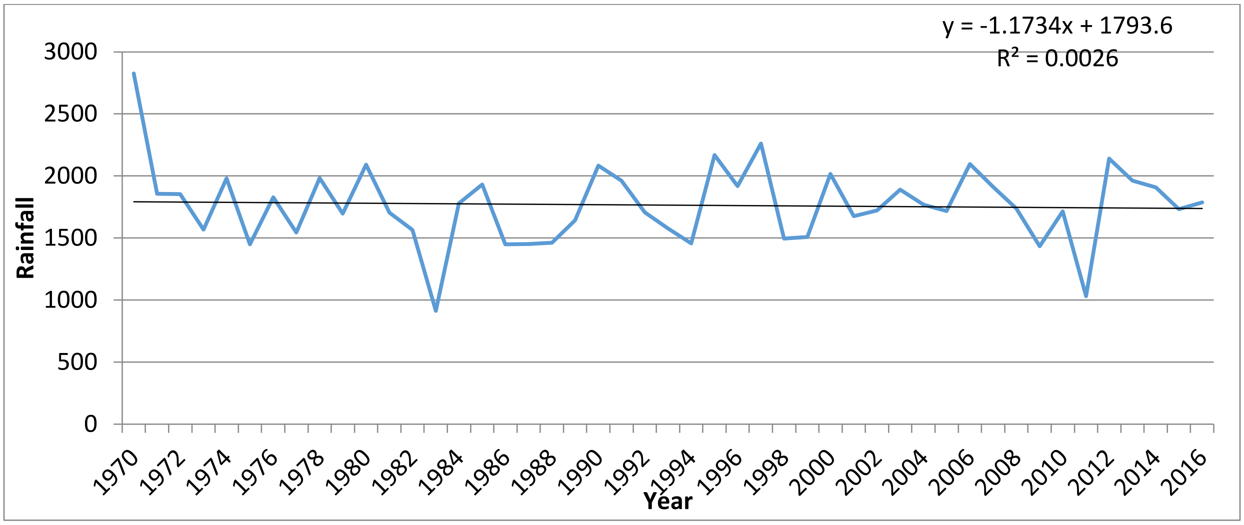

Fig 5.6: Trend plot of Rainfall variations between 1970 and 2016

While the trend is not statistically significant with a coefficient of 0.044 at 0.05 level of confidence, it is evident that the rainfall is decreasing at an annual rate shown by the slope of the regression coefficient (b = -1.173). The trend plot of rainfall shows that at the start of the climatic period (1970-2016), rainfall increase was recorded for the first decade (1970-1987) after which a decreasing pattern of rainfall has been noticed for the study area with intermittent increase in some years. However, the former was found to be more pronounced from 1980 to 1989 and after 2000s till date than the latter. A similar decreasing trend in rainfall was recorded, but for the northern part of Nigeria, by Odjugo (2010) but an increasing trend in some parts of the south.

The mean annual rainfall for the 47year period is 1765.4mm. A graph of rainfall anomaly (fig 5.7) was also shown to give a clearer picture on rainfall condition in the study area. The rainfall anomalies relative to 1970 –2016 normal bear evidence to a more recent decrease in the rainfall trend, which was more from the early 2000s. Between 1970 and 1979, mean annual rainfall was above the 1970-2016 normal, between 1980 to 1989, it was below the climatic normal giving a mean decadal rainfall value of 1599.2mm while from 1990 – 1999, the mean annual rainfall for this decade increased to 1814mm. however, from early 2000s till date, the rainfall pattern of Enugu has exhibited a decreasing trend given that the mean annual rainfall for the 2000 to 2009 decade yielded a value of 1797.5mm while the mean annual rainfall recorded for the period 2010 to 2016 was 1754.1mm, a value slightly below the climatic mean of 1765.4mm of rainfall. Furthermore, fig 5.7 shows that the years with rainfall values above normal are less; 24 out of the 47 years were below normal but only 23 years (48.9%) out of the 47 years were above the normal.

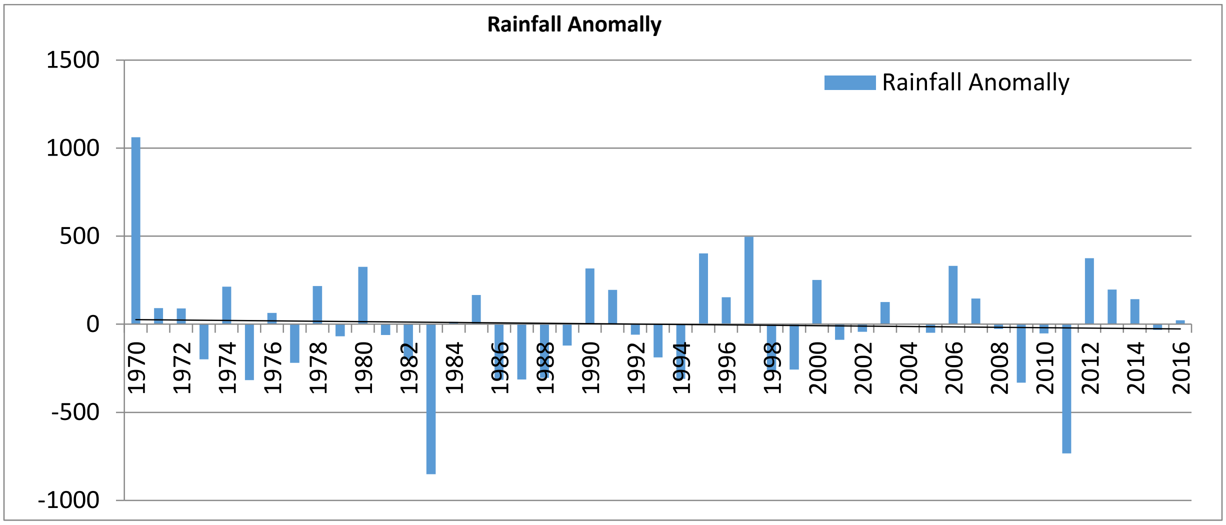

Fig 5.7: Rainfall anomaly in Enugu using 1970–2016 normal

The relative humidity scenario in Enugu is shown clearly in figure 5.8. The data was obtained from the records of the Nigerian Meteorological Agency. The monthly humidity data were summed anually to generate annual time series of relative humidity from 1970 to 2016. The trend plot of humidity achieved is shown in fig 5.8 and this was found not to be statistically significant, given a coefficient of 0.055 at 0.05 level of confidence. It is evident that relative humidity is reducing at an annual rate shown by the slope of the regression coefficient (b = -0.06). Mean relative humidity of Enugu is 73.7%. Though the rate of reduction of humidity given the slope value is quite insignificant, the negative trend is indicative of the direction of this movement. Relative humidity indicates the degree of saturation of the air i.e. how close to saturation the air is. This is greatly influenced by air temperature because the capacity of air to hold moisture increases with temperature.

Thus the relative humidity of air increases as temperature decreases or decreases as temperature increases. The humidity scenario in Enugu is, however, expected due the observed increase in temperature pattern. This is a worrisome development both to urban dwellers and the building industry. This is even more disturbing given the rainfall trend which has shown a slightly decreasing annual rainfall. If the scenario persists, there could be serious implications regarding construction cost, maintenance and energy consumption.

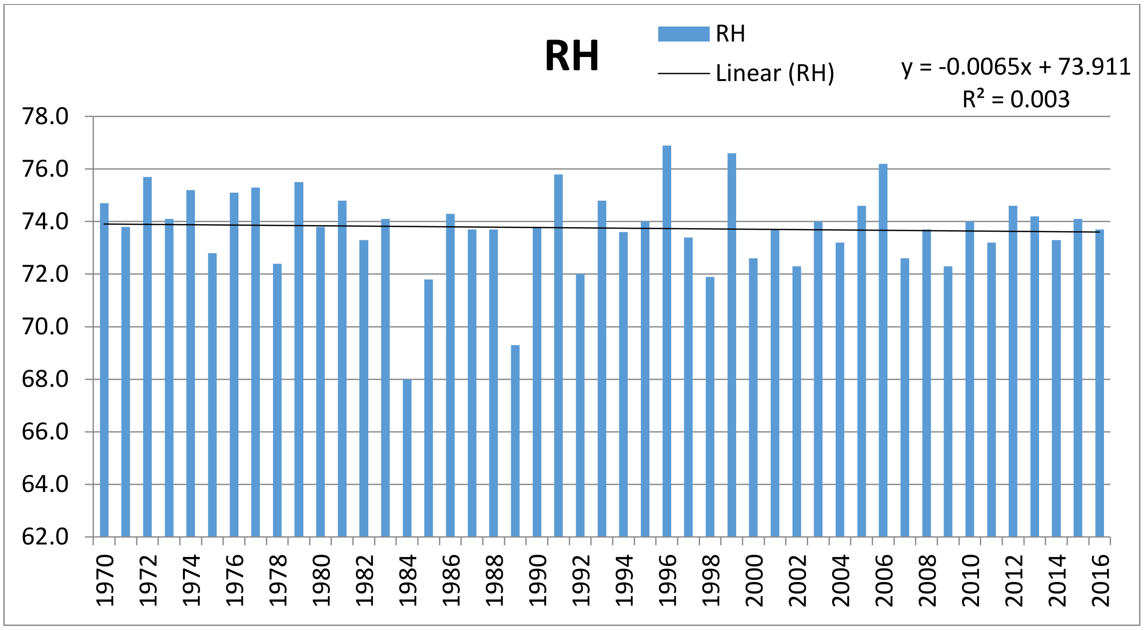

Fig 5.8: Trend plot of Relative Humidity variations between 1970 and 2016

Moreover, the climate scenario in Enugu as depicted earlier gives an indication of a warming urban climate with potential less availability of moisture overtime if this persists. Though rainfall is shown to be on a slight negative trend, it is important to note that the annual rainfall is still high and a major contributor to the recurrent flood problems witnessed in Enugu in recent times.

The research questionnaires were designed with variables from the exploratory studies, this was supplied by the interviewees and the literature survey. The design intends to obtain representative views of the respondents on the levels of importance or relative impact of climate change on the design of building, building materials, cost of construction and maintenance and energy use on buildings in Enugu metropolis, each attribute being rated. Lickert scales were provided on a rating continuum (1-5) to measure the varying degrees of respondents' opinions about the relative worth of the attributes in the subsets. Lickert scale is used in measuring opinions, beliefs and attitudes, Agresti and Franklin (2007). In the field of organizational research, a range of response between 30 and 90 is acceptable according to Bryman and Bell (2003). The rest of the questionnaires were either not returned or improperly completed, therefore invalid. No specific reason was given by the respondents for the uncompleted questionnaires.

On the perception of the respondents regarding a possible changing climate, the respondents were asked through the interview section of the questionnaire if they are quite aware of these climate possibilities in other to ascertain their level of awareness and to obtain their opinion and any experiences they could have regarding climate impacts on aspects of the building sector in Enugu metropolis.

However, much of the evidences are the seasonal variations, the uncertainties in the expected period of rainfall both the arrival of first rain and the expected end or what could easily be referred to as onset and cessation of rains. Thus, series of questions were enumerated and their answers sought. Regarding whether building design has changed over the years and if they think that the changes are as a result of climate changes, the interviewees unanimously agreed that building design has changed while they partly agreed that climate change has its contribution. Amongst the respondents, this climate factor is a smaller percentage compared to a desire for new innovation. Their observed changes involve the following though not limited to these: new roofing sheet, roofing pattern, new window pattern and new ceiling materials.

Objective 2: To determine the contributions of climate to changes in building design

Here, the opinions of the respondents on the contribution of climate to changes in building design will be examined. Table 5.3 contains the responses of the respondents on the contribution of climate change to changes in building design.

As shown in table 5.3, it is clearly shown that a huge number of the respondents agreed that the building characteristics in Enugu have witnessed tremendous changes; about 196 and 111 of the respondents strongly agreed and agreed respectively that the building designs in Enugu have changed over time. Equally, about 199 of these respondents strongly agreed that part of the observed changes in designs is in window designs. For the result of the observed changes, 125 agreed that this is attributed to changes and advancements in technology. On the contributions of climate to these changes, i.e. as part of the determinant factors, 93 of the respondents strongly disagreed while other 93 were neutral.

On the other hand, a total of 102 strongly agreed and agreed that climate is part of the causative factors to the changes in building designs in Enugu. For the consideration of climatic parameters in building designs, all the respondents agreed that this is a possibility in the study area. This follows from the fact that in one way of the other, the persons involved in construction would make decisions regarding the positions of the building, positioning of openings such as windows and doors to ensure maximum illumination of the indoors of such buildings by sunshine during the day while trying to maintain maximum ventilation. This position was further reiterated as shown by the response of the respondents whereby about 88 and 149 of them agreed and strongly agreed that climate parameters are the main factors considered in window designs and ventilation in buildings.

The lickert table with a cluster means value of 4.01 > 3.0 and associated standard deviation of 0.65 indicates that the respondents perceived climate changes as contributing to changes in building designs. Particularly, the result shows that there are stages in the design of buildings whereby climate parameters are considered and affects important decision regarding the supposed buildings.

Table 5.3: Climate Contributions to Changes in Building Design

Question Items SA=5, A=4,UD=3,D=2,SD=1						Statistics	
	SA	**A**	**UD**	**D**	**SD**	**Mean**	**STD**
Building design has changed over the past five decades	196	111	9	9	0	**4.5**	**0.86**
Roofing has changed over the past five decades	208	100	17	-	-	**4.6**	**0.9**
There has been a continuous evolution of new window designs over the past five decades	199	99	18	9	-	**4.5**	**0.85**
The change is as a result technological innovation	62	125	27	71	40	**3.3**	**0.38**
The change is aimed at containing environmental condition and climate change	90	145	63	27	-	**3.9**	**0.56**
Building pattern in Enugu metropolis has changed over the past five decades due climate change	51	51	93	93	37	**3.0**	**0.26**
Climate parameters are put into consideration when designing	197	128	-	-	-	**4.6**	**0.92**
Climate parameters are considered when designing windows and other openings	106	149	31	31	8	**3.9**	**0.57**
The effect of new design can only be contain by critically considering climatic factors	83	150	58	25	9	**3.8**	**0.56**
Cluster Mean and Standard Deviation						**4.01**	**0.65**

Source: Researcher field survey 2017

Objective 3: To determine the effects of climate on the Cost of Construction and Maintenance.

The objective seeks to examine the responses of the respondents on the effects of climate on the cost of construction and maintenance. The responses of the respondents on the above objective are presented in table 5.4.

The responses from table 5.4 show that despite the fact that most respondents agreed that construction cost and maintenance cost have increased over the years, they attributed these to economic situations particularly the recession. Thus majority of the respondents, about 125 strongly disagreed that changing climate conditions has affected the construction cost of building. Also, about 77 of the respondents were undecided on this question while only 62 and 15 of the respondents agreed and strongly agreed respectively that climate change has affected cost of construction. Contrarily, these respondents still believed that variations in climatic parameters have caused deteriorations in buildings. On this, 108 and 147 strongly agreed and agreed that this position is true as they gladly emphasized that climate factors are reducing the life span of most of the buildings. These climatic factors were also believed by the respondents to have been the reason why colours of paints on buildings change and easily deteriorate. About 111 of the respondents strongly agreed that rainfall affects the cost of maintaining buildings in the study area as well as the cost of construction.

On the other hand, 133 agreed and supported the assertion that rainfall is one climatic parameter affecting cost if construction and maintenance of buildings in the study area. Similarly, 59 and 133 of the respondents strongly agreed and agreed the temperature, as a climate parameter, also influence cost of construction and maintenance. In the same vein, the respondents also agreed that wind also affects greatly the cost of maintaining buildings as well as actual construction. In support of this, the clusters mean value of 3.9, slightly above the lickert average of 3.0 and associated standard deviation of 0.65 (lickert standard deviation) indicates that there are reasons for variations in the cost of construction and maintenance of buildings.

Table 5.4: Perceptions of effects of Climate on the Cost of Construction and Maintenance

Question Items SA=5, A=4, UD=3, D=2, SD=1	SA	A	UD	D	SD	Statistics	
						Mean	STD
The cost of construction has increased over the past five decades	287	23	15	0	0	**4.8**	**1.24**
The cost of building maintenance has increased over the past five decades	249	68	8	0	0	**4.7**	**1.07**
The increase is as a result of the present day recession	143	71	24	63	24	**3.8**	**0.49**
Climate change has affected the cost of building construction	15	62	77	125	46	**2.6**	**0.41**
Climate change has caused buildings to be deteriorated without living out their life span	108	147	16	54	0	**4.0**	**0.62**
climate change is the cause of changes in building color shortly after painting	111	138	41	35	0	**4.0**	**0.57**
High rainfall affects the cost of building construction and maintenance	111	133	29	52	0	**3.9**	**0.56**
Temperature change affects cost of construction and maintenance	59	133	66	52	15	**3.5**	**0.43**
Wind variations affects cost of construction and maintenance	85	131	70	23	16	**3.8**	**0.47**
Cluster Means and Standard Deviations						**3.9**	**0.65**

Source: Researcher field survey 2017

Objective 4: To determine the Perceptions of the respondents on the impacts of Climate on Construction Materials Used.

This objective sought to examine the responses of the respondents on the impacts of climate on construction materials used. The responses for the objective are contained in table 5.5.

Table 5.5: Perceptions of impacts of Climate on Construction Materials Used

Question Items SA=5, A=4, UD=3, D=2, SD=1	SA	A	UD	D	SD	Statistics	
						Mean	**STD**
The materials used for building construction have changed over the last three decades.	167	92	33	25	8	**4.2**	**0.65**
The newly evolving building materials are more climate compliant and lasts longer.	67	158	42	42	16	**3.7**	**0.55**
The new designs and types building materials are more expensive and requires higher technology.	145	94	60	17	9	**4.1**	**0.56**
The new technologies in building materials are only beautiful without any consideration of climatic variables.	42	92	57	92	42	**3.0**	**0.25**
The transition from ordinary Zinc to Aluminum and to Metro-coppa, metro tiles and Stone Coated type of roofing is of climate change adaptation essence.	100	117	42	58	8	**3.7**	**0.44**
Green roofing is adopted to contain the impacts of climate change	58	100	67	67	33	**3.3**	**0.24**
Hydro foam is adopted to contain the impacts of climate change	34	137	77	43	34	**3.3**	**0.44**
Natural Bricks is adopted to contain the impacts of climate change	33	158	67	42	25	**3.4**	**0.54**
Stone coated roofing is adopted to contain the impacts of climate change	25	158	75	42	25	**3.4**	**0.56**
Cluster Mean and Standard deviate on						**3.6**	**0.47**

Objective 5: To examine the perceptions of the respondents on the impacts of climate on energy needs.

This objective sought to examine the perceptions of the respondents on the impacts of climate change on energy needs.

The result is presented in table 5.6 and discussed afterwards.

From table 5.5, it will be observed that a total of 167 and 158 of these respondents strongly agreed and agreed that the materials used for building and construction has changed and that they believed that the newly evolving building materials are climate compliant respectively.

In the same vein, while the respondents acknowledged that the evolving new building materials are expensive and requires new technologies, it was also clearly shown that these are only beautiful without the consideration of climate impacts. As depicted in table 5.5, a good number of the respondents agreed and strongly agreed that the transition from zinc roofing system to aluminum, metro tiles and stone coated roofing system are part of climate change adaptation. Also, majority of the respondents agreed that the adaptation and adoption of green roofing is to contain the impacts of climate change on structures while about 67 of the respondents strongly disagreed to this as another 67 remained neutral to the inquiry. Similarly, a good majority, about 137 and 158, of the respondents believed that the adoption of hydra foam and natural bricks are part of the adaptation mechanisms in the building industry to contain the supposed impacts of a changing climate to buildings.

In other words, the responses from the respondents revealed that they are quite knowledgeable about the effects of climate change and its parameters on buildings and perceived that the nature of changing construction materials were targeted at adapting buildings the possible impacts of a changing climate. They acknowledged that though these materials are changing and sometimes expensive but that they are not good enough if climate is not considered in their development. The result also shows that though the newly evolving building materials and technologies are good and are very functional, they would fail the aim of their invention and as such still become dysfunctional despite their expensive nature if they are not tailored to adapt to the tropical environment which is characterized by excessive rainfall impacts, high temperatures and humidity etc.; they may be easily waterlogged or penetrated during rainfall.

Table 5.6: Perceptions on Climate impacts on Energy Needs

Question Items SA=5,A=4,UD=3,D=2,SD=1	SA	A	UD	D	SD	Statistics	
						Mean	**STD**
Energy need in buildings in Enugu metropolis varied over the last three decades.	83	150	58	25	9	**3.8**	**0.56**
The variation in energy needs of buildings in Enugu is a product of climate variations	20	120	86	79	20	**3.1**	**0.44**
Does temperature change/increase affect the energy need of a building?	142	92	33	33	25	**3.9**	**0.51**
Does amount and intensity of rainfall affect the energy need of a building?	111	128	51	26	9	**3.9**	**0.52**
Does wind direction affect the energy need of a building?	63	108	72	45	37	**3.4**	**0.28**
Does Humidity and Cloud Cover affect the energy need of a building?	83	133	75	17	17	**3.8**	**0.49**
Does sunshine intensity affect the energy need of a building?	137	120	51	17	0	**4.2**	**0.61**
Heating up of the building increases the energy need in building	108	125	42	42	8	**3.9**	**0.49**
Cooling down of the building increases the energy need in building	94	111	60	43	17	**3.7**	**0.38**
Cluster Means and Standard Deviation						**3.7**	**0.48**

Source: researcher field survey 2017

Table 5.6 shows the response of the respondents on what they perceived as constraints by climate variability and change on energy needs in buildings. Most of the respondents agreed that the changes in energy needs of buildings are a product of climate variations whereas about 86 of them were indifferent about this assertion while 79 disagreed strongly that changes in energy needs has no relationship with climate variations or change. In addition, the respondents agreed, as about 142 and 92 agreed strongly that temperature is a determinant factor in energy needs in buildings by occupants of these structures. In the same vein, they agreed that wind also determines the level of energy need and rates of energy consumption by buildings in Enugu metropolis. Another effect of climate variations on level of energy needs in buildings that received strong agreement from the respondents is the humidity levels in these buildings and the challenge of maintaining the humidity levels to ensure comfort especially on days with overcast cloud cover. They also agreed that amount of sunshine and sunshine intensity entering buildings determines the level of energy need.

More so, 108 and 125 of the respondents agreed at various degrees that the need to heat up of buildings or the reverse of it increases energy cost and consumption.

Cost in energy consumption could be reduced greatly if changing or varying climatic conditions of the concerned sites are put into proper consideration. For instance, when buildings are properly oriented in relation the sunrise and direction of sunrise and sunset, this may lead to energy savings as the sunlight while continuously illuminate the inside of buildings especially throughout the day such that there may not be any need to use electric bulbs to illuminate buildings during the day.

Objective 6: develop a model for predicting the effects of climate variability on building design, building materials, energy use, maintenance and construction cost.

To do this, Poisson Regression was performed using the data presented in tables 5.7a and 5.7b. The aim was to examine if the dependent variables (cost of construction, materials and maintenence, energy needs) affect the climatic variables namely: rainfall, sunshine intensity, temperature (maximum and minimum), effective rainfall, wind speed and relative humidity. The results of the Poisson Regression are presented in tables below.

Table 5.7: Perceptions of the respondents on time variations in aspects of building considered

Month	Cost of Energy	Cost of Maintenance	Building Design Performance
January	33	11	33
February	46	16	21
March	39	37	19
April	34	29	22
May	13	35	15
June	13	31	51
July	19	41	43
August	37	27	19
September	11	17	29
October	20	41	27
November	27	13	17
December	33	27	30

Table 5.7a: Field Data of the Meteorological Variables

Months	Rn	S.I.	Tmax	Ws	Tmin	Rh	Eff. Rn
Jan	11.7	6.1	33.4	5.7	21.0	54.9	11.5
Feb	18.0	6.2	34.8	5.7	22.7	60.8	17.5
Mar	67.9	5.8	34.6	6.3	23.9	68.3	60.5
Apr	148.2	6.1	33.4	6.0	23.7	74.5	113.1
May	236.2	6.0	31.8	5.2	23.0	79.4	146.9
Jun	260.7	5.1	30.5	5.2	22.4	81.8	151.1
Jul	247.1	3.7	29.4	5.4	22.2	83.1	149.4
Aug	219.8	3.5	29.2	5.4	22.2	83.4	142.5
Sep	296.9	4.1	29.9	4.8	22.1	83.3	154.7
Oct	213.9	5.4	30.9	4.5	22.0	80.8	140.7
Nov	27.4	7.0	32.5	4.2	21.8	72.7	26.2
Dec	7.4	6.8	33.0	5.0	20.1	61.3	7.3

Table 5.7b: Meteorological Variables and their Parameterization

S/N	Variables	Code	Label	Parameterisation
1	Rainfall	X1	Rn	Weather Observation Value
2	Sunshine Intensity	X2	S.I.	Weather Observation Value
3	Maximum Temperature	X3	Tmax	Weather Observation Value
4	Wind speed	X4	Ws	Weather Observation Value
5	Minimum Temperature	X5	Tmin	Weather Observation Value
6	Relative Humidity	X6	Rh	Weather Observation Value
7	Effective Rainfall	X7	Eff. Rn	Calculated from Rainfall using CropWat model

Table 5.8a Poisson Regression of Cost of Energy (as dependent variable) against Rn, SI, Tmax, Ws, Tmin, Rh and Eff. Rn

Coefficients	Estimate	Std. Error	Z Value	Pr(>|z|)	
(Intercept)	1.52934	4.33068	0.353	0.72398	
Rn	-0.01650	0.00518	-3.186	0.00144 **	
SI	-0.41782	0.20059	-2.083	0.03725 *	
Tmax	0.20829	0.22989	0.906	0.36491	
Ws	-0.02085	0.27899	-0.075	0.94043	
Tmin	-0.16488	0.22957	-0.718	0.47263	
Rh	0.02126	0.03743	0.568	0.57001	
Eff.Rn	0.02075	0.01050	1.976	0.04815 *	

From this table, we can say that it is only three variables (factors) that significantly affect cost of energy in the study area; they are rainfall, sunshine intensity and effective rainfall. This implies that these three factors do affect the energy cost of building in the study area.

The model corresponding to this Poisson Regression is

$$n_i = -0.01650X_1 - 0.41782X_2 + 0.02075X_7 \qquad 5.1$$

Table 5.8b Poisson Regression of Cost of Maintenance (as dependent variable) against Rn, SI, Tmax, Ws, Tmin, Rh and Eff. Rn

Coefficients	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
(Intercept)	-11.011463	5.740199	-1.918	0.05507 .
Rn	-0.008974	0.003851	-2.331	0.01977 *
SI	-0.215216	0.181035	-1.189	0.23452
Tmax	0.697005	0.256868	2.713	0.00666 **
Ws	0.536338	0.267109	2.008	0.04465 *
Tmin	-0.893465	0.275905	-3.238	0.00120 **
Rh	0.129563	0.049981	2.592	0.00954 **
Eff.Rn	0.021145	0.008463	2.499	0.01247 *

From the table, we can see that it is only one factor that does not affect cost of maintenance of building in the study area; that is Sunshine Intensity. The rest of the factors; Rainfall, Maximum Temperature, Wind speed, Minimum temperature, Relative humidity and Effective Rainfall all did affect cost of maintenance of building.

The model corresponding to this table is given by:

$$n_i = -11.011463 - 0.008974X_1 + 0.697005X_3 + 0.536338X_4 - 0.893465X_5 + 0.129563X_6 + 0.021145X_7$$

The model is in line with the listed factors that affect cost of maintenance, together with the intercept.

Table 5.8c Poisson Regression of Building Design Performance (as dependent variable) against Rn, SI, Tmax, Ws, Tmin, Rh and Eff. Rn

Coefficients	Estimate	Std. Error	Z Value	Pr(>|z|)
(Intercept)	7.835259	4.673380	1.677	0.0936
Rn	0.007732	0.004121	1.876	0.0606
SI	0.207943	0.186112	1.117	0.2639
Tmax	-0.131036	0.233687	-0.561	0.5750
Ws	0.571588	0.280350	2.039	0.0415 *
Tmin	-0.226017	0.239649	-0.943	0.3456
Rh	0.004794	0.038718	0.124	0.9015
Eff.Rn	-0.010675	0.009492	-1.125	0.2608

From the table, we see that it is only Wind Speed that significantly affects Building Design Performance in the study area.

Also, the model for this Poisson Regression is presented thus:

$$n_i = 0.571588X_4 \qquad (5.3)$$

Tests of Hypotheses

The various hypotheses postulated will be tested and their results will be presented in this section.

Hypothesis one: There is no significant variation in climate parameters (1957–2017).

Statistical Tool Used: Trend Analysis

Reason for Choice of Tool: To check the trend variation over a period of time.

Decision and Reason for Decision: It was observed from objective one that there have been variations in the climate parameter over the assessment period in the study area.

Hypothesis Two: The perceptions of the respondents on the effects of climate variability on building design are not significant.

Statistical Tool Used: One Sample T – Test.

Reason for Choice of Tool: One level of observation was compared with a known standard.

Decision Rule: reject the null hypothesis if the p – value is less than 0.05, otherwise accept it.

One Sample T–Test for Climate Contribution to Changes in Building Design

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Climate Contribution to Changes in Building Design	9	4.0000	.59161	.19720

One-Sample Test

	Test Value = 3.0					
					95% Confidence Interval of the Difference	
	t	Df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Climate Contribution to Changes in Building Design	5.071	8	.001	1.00000	.5452	1.4548

Decision and Reason for Decision: The result showed a p–value of 0.001, less than 0.05. The implication is that the overall (cluster) weighted mean of the respondents is significantly above 3.0; (that is 4.0 > 3.0, with a p – value of 0.001). This implies that based on the responses of the respondents, climate contributes significantly to changes in building design at 0.05 level of significance.

Hypothesis Three: The perceptions of the respondents on effects of climate variability on cost of building construction and maintenance are not significant,

Statistical Tool Used: One Sample T – Test.

Reason for Choice of Tool: One level of observation was compared with a known standard.

Decision Rule: reject the null hypothesis if the p – value is less than 0.05, otherwise accept it.

One Sample T–Test for Perceptions on Climate effects on the cost of construction and maintenance

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Perceptions on Climate effects on the cost of construction and maintenance	9	3.9000	.64614	.21538

One-Sample Test

	Test Value = 3.0					
					95% Confidence Interval of the Difference	
	t	Df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Perceptions on Climate effects on the cost of construction and maintenance	4.179	8	.003	.90000	.4033	1.3967

Decision and Reason for Decision: The result of this one sample T – Test showed that the responses of the respondents are significant. This is because the p – value of 0.003 was gotten; more so, the overall (cluster) weighted mean is 3.9 which is above 3.0. This means that according to the respondents, climate significantly affects the cost of construction and maintenance at 0.05 significance level.

Hypothesis Four: The perceptions of the respondents on impacts of climate variability on the energy need in buildings are not significant.

Statistical Tool Used: One Sample T – Test.

Reason for Choice of Tool: One level of observation was compared with a known standard.

Decision Rule: reject the null hypothesis if the p – value is less than 0.05, otherwise accept it.

One Sample T–Test for Perceptions on Climate impacts on Construction Materials Used

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Perceptions on Climate impacts on Construction Materials Used	9	3.5667	.39370	.13123

One-Sample Test

	Test Value = 3.0					
					95% Confidence Interval of the Difference	
	t	Df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Perceptions on Climate impacts on Construction Materials Used	4.318	8	.003	.56667	.2640	.8693

Decision and Reason for Decision: It was found from the One Sample T – Test that climate significantly impacted the construction materials used; that is the issues raised in the questionnaire are significant climate impacts on the construction materials used. This is because the p –value of the One Sample T – Test is 0.003, less than 0.05; with an overall mean of 3.5667>3.0.

Hypothesis Five: The Perceptions of the respondents on impacts of Climate on Energy Needs are not significant

Statistical Tool Used: One Sample T – Test.

Reason for Choice of Tool: One level of observation was compared with a known standard.

Decision Rule: reject the null hypothesis if the p – value is less than 0.05, otherwise accept it.

One Sample T–Test for Perceptions on Climate impacts on Energy Needs

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Perceptions on Climate impacts on Energy Needs	9	3.7444	.32059	.10686

One-Sample Test

	Test Value = 3.0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Perceptions on Climate impacts on Energy Needs	6.966	8	.000	.74444	.4980	.9909

Decision and Reason for Decision: The result of the one sample T–Test above showed that the questions asked the respondents are significant climate impacts on energy needs. This is because the p – value is 0.000 which is less than 0.05, the overall (cluster) mean being 3.7444>3.0.

Presentation of Principal Components Analysis Results

Principal Components Analyses were carried out using the responses from the questionnaires.

Table 5.7a PCA Analysis of Perceived Climate Contribution to Changes in Building Design (KMO and Bartlett's Test).

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.894
Bartlett's Test of Sphericity	Approx. Chi-Square	5642.364
	Df	36
	Sig.	.000

Looking at the table, we see that the Kaiser-Meyer-Olkin Measure of Sampling Adequacy, the value is 0.894 which is greater than 0.80 and the Bartlett's Test of Sphericity is 0.000. These imply that we can go on to run valid principal components analysis; that is, the prerequisite for conducting PCA.

Table 5.7b: Communalities of Perceived Climate Contribution to Changes on Building Design

Communalities

	Initial	Extraction
Building design has changed over the past five decades	1.000	.877
Roofing has changed over the past five decades	1.000	.883
There has been a continuous evolution of new window designs over the past five decades	1.000	.902
The change is as a result technological innovation	1.000	.928
The change is aimed at containing environmental condition and climate change	1.000	.866
Building pattern in Enugu metropolis has changed over the past five decades due climate change	1.000	.830
Climate parameters are put into consideration when designing	1.000	.807
Climate parameters are considered when designing windows and other openings	1.000	.870
The effect of new design can only be contain by critically considering climatic factors	1.000	.881

Extraction Method: Principal Component Analysis.

Table 5.7c Explanation of Total Variance of Perceived Climate Contribution to Changes on Building Design

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.845	87.167	87.167	7.845	87.167	87.167
2	.472	5.240	92.408			
3	.303	3.372	95.779			
4	.129	1.431	97.211			
5	.094	1.041	98.252			
6	.067	.745	98.996			
7	.037	.410	99.406			
8	.034	.377	99.783			
9	.020	.217	100.000			

Extraction Method: Principal Component Analysis.

From the table, we can see that only one factor was extracted and it explained about 87.167% of the total variance. This implies that the PCA extracted (explained) about 87.167 percent of the information contained in the data from the responses of the respondents on perceived climate contribution to changes on building design.

Table 5.7d: Component Matrix of Perceived Climate Contribution to Changes on Building Design

Component Matrix[a]

	Component
	1
The change is as a result technological innovation	.964
There has been a continuous evolution of new window designs over the past five decades	.950
Roofing has changed over the past five decades	.940
The effect of new design can only be contain by critically considering climatic factors	.939
Building design has changed over the past five decades	.936
Climate parameters are considered when designing windows and other openings	.933
The change is aimed at containing environmental condition and climate change	.931
Building pattern in Enugu metropolis has changed over the past five decades due climate change	.911
Climate parameters are put into consideration when designing	.898

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

The principal component is strongly correlated with all the original variables. That is, only principal component increases with increasing.

This component can be viewed as a measure of the quality of these variables; The change is as a result technological innovation, There has been a continuous evolution of new window designs over the past five decades, Roofing has changed over the past five decades, The effect of new design can only be contain by critically considering climatic factors, Building design has changed over the past five decades, Climate parameters are considered when designing windows and other openings, The change is aimed at containing environmental condition and climate change, Building pattern in Enugu metropolis has changed over the past five decades due climate change, Building pattern in Enugu metropolis has changed over the past five decades due climate change, and Climate parameters are put into consideration when designing.

The implication of this result is that other variables tend to increase as “the change is as a result technological innovation” increases and they also tend to decrease as “the change is as a result technological innovation” decreases.

This component can be viewed as a measure of the quality of these variables;

1. climate change is the cause of changes in building color shortly after painting,
2. High rainfall affects the cost of building construction and maintenance,
3. Wind variations affects cost of construction and maintenance,
4. Climate change has caused buildings to be deteriorated without living out their life span,
5. Temperature change affects cost of construction and maintenance,
6. The increase is as a result of the present day recession,
7. The cost of building maintenance has increased over the past five decades,
8. Climate change has affected the cost of building construction and
9. The cost of construction has increased over the past five decades.

Table 5.8a: PCA Analysis of Perceptions on the effects of climate change on the cost of construction and Maintenance (KMO and Bartlett's Test).

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.907
Bartlett's Test of Sphericity	Approx. Chi-Square	5359.774
	Df	36
	Sig.	.000

From the table, we see that the Kaiser–Meyer–Olkin Measure of Sampling Adequacy is 0.907, while the Bartlett’s Test of Sphericity has a p–value of 0.000. The values of these show that we can go ahead with the PCA.

Table 5.8b: Communalities on Analysis of Perceptions on the effects of climate change on the cost of construction and Maintenance

	Initial	Extraction
The cost of construction has increased over the past five decades	1.000	.551
The cost of building maintenance has increased over the past five decades	1.000	.771
The increase is as a result of the present day recession	1.000	.890
Climate change has affected the cost of building construction	1.000	.768
Climate change has caused buildings to be deteriorated without living out their life span	1.000	.922
climate change is the cause of changes in building color shortly after painting	1.000	.946
High rainfall affects the cost of building construction and maintenance	1.000	.940
Temperature change affects cost of construction and maintenance	1.000	.902
Wind variations affects cost of construction and maintenance	1.000	.924

Extraction Method: Principal Component Analysis.

Table 5.8c: Total Variance Explained on Analysis of Perceptions on the effects of climate change on the cost of construction and Maintenance

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.615	84.612	84.612	7.615	84.612	84.612
2	.604	6.706	91.318			
3	.319	3.546	94.865			
4	.189	2.097	96.962			
5	.100	1.113	98.075			
6	.076	.844	98.919			
7	.049	.541	99.461			
8	.032	.360	99.821			
9	.016	.179	100.000			

Extraction Method: Principal Component Analysis.

The PCA extracted about 84.612% of the total variance; that is about 84.612 percent of the variability in the data from the responses of the respondents on their perceptions on the effects of climate change on the cost of construction and maintenance.

Table 5.8d: Component Matrix Analysis of Perceptions on the effects of climate change on the cost of construction and Maintenance

	Component
	1
The cost of construction has increased over the past five decades	.742
The cost of building maintenance has increased over the past five decades	.878
The increase is as a result of the present day recession	.943
Climate change has affected the cost of building construction	.877
Climate change has caused buildings to be deteriorated without living out their life span	.960
climate change is the cause of changes in building color shortly after painting	.973
High rainfall affects the cost of building construction and maintenance	.970
Temperature change affects cost of construction and maintenance	.950
Wind variations affects cost of construction and maintenance	.961

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

The principal component is strongly correlated with all the original variables. That is, only principal component increases with increasing.

This component can be viewed as a measure of the quality of these variables;

1. climate change is the cause of changes in building color shortly after painting,
2. High rainfall affects the cost of building construction and maintenance,
3. Wind variations affects cost of construction and maintenance,
4. Climate change has caused buildings to be deteriorated without living out their life span,
5. Temperature change affects cost of construction and maintenance,
6. The increase is as a result of the present day recession,
7. The cost of building maintenance has increased over the past five decades,
8. Climate change has affected the cost of building construction and
9. The cost of construction has increased over the past five decades.

Table 5.9a: PCA Analysis of Perceptions on the impacts Climate on Construction Materials (KMO and Bartlett's Test).

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.927
Bartlett's Test of Sphericity	Approx. Chi-Square	6285.655
	Df	36
	Sig.	.000

Looking at the table, we see that the Kaiser-Meyer-Olkin Measure of Sampling Adequacy, the value is 0.927 which is greater than 0.80 and the Bartlett's Test of Sphericity has a p–value of 0.000. These imply that we can go on to run valid principal components analysis.

Table 5.9b Communalities Analysis of Perceptions on the effects of climate change on the Building Material

	Initial	Extraction
The materials used for building construction have changed over the last three decades.	1.000	.912
The newly evolving building materials are more climate compliant and lasts longer.	1.000	.907
The new designs and types building materials are more expensive and requires higher technology.	1.000	.911
The new technologies in building materials are only beautiful without any consideration of climatic variables.	1.000	.881
The transition from ordinary Zinc to Aluminum and to Metro-coppa, metro tiles and Stone Coated type of roofing is of climate change adaptation essence.	1.000	.915
Green roofing is adopted to contain the impacts of climate change	1.000	.929
Hydro foam is adopted to contain the impacts of climate change	1.000	.951
Natural Bricks is adopted to contain the impacts of climate change	1.000	.946
Stone coated roofing is adopted to contain the impacts of climate change	1.000	.941

Extraction Method: Principal Component Analysis.

Table 5.9c: Total variance explained analysis of perceptions on the effects of climate change on the Building Materials

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.294	92.153	92.153	8.294	92.153	92.153
2	.195	2.170	94.323			
3	.163	1.815	96.138			
4	.128	1.427	97.564			
5	.075	.833	98.398			
6	.059	.653	99.050			
7	.037	.412	99.463			
8	.031	.346	99.809			
9	.017	.191	100.000			

Extraction Method: Principal Component Analysis.

The Total Variance Explained is 92.153%, which means that the PCA explained about 92.153% of the total variability.

Table 5.9d: Component matrix on analysis of perceptions on the effects of climate change on Building Materials

	Component
	1
The materials used for building construction have changed over the last three decades.	.955
The newly evolving building materials are more climate compliant and lasts longer.	.952
The new designs and types building materials are more expensive and requires higher technology.	.954
The new technologies in building materials are only beautiful without any consideration of climatic variables.	.939
The transition from ordinary Zinc to Aluminum and to Metro-coppa, metro tiles and Stone Coated type of roofing is of climate change adaptation essence.	.957
Green roofing is adopted to contain the impacts of climate change	.964
Hydro foam is adopted to contain the impacts of climate change	.975
Natural Bricks is adopted to contain the impacts of climate change	.972
Stone coated roofing is adopted to contain the impacts of climate change	.970

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

The principal component is strongly correlated with all the original (nine) variables. That is, only principal component increases with increasing.

This component can be viewed as a measure of the quality of these variables:

1. Hydro foam is adopted to contain the impacts of climate change,
2. Natural Bricks is adopted to contain the impacts of climate change,
3. Stone coated roofing is adopted to contain the impacts of climate change,
4. Green roofing is adopted to contain the impacts of climate change,
5. The transition from ordinary Zinc to Aluminum and to Metro-Coppa, metro tiles and Stone Coated type of roofing is of climate change adaptation essence,
6. The materials used for building construction have changed over the last three decades,
7. The new designs and types building materials are more expensive and requires higher technology,
8. The newly evolving building materials are more climate compliant and lasts longer and
9. The new technologies in building materials are only beautiful without any consideration of climatic variables.

Table 5.10a: PCA Analysis of Perceptions of the effects Climate Change on Energy Needs in Buildings (KMO and Bartlett's Test)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.923
Bartlett's Test of Sphericity	Approx. Chi-Square	6540.059
	Df	36
	Sig.	.000

The Kaiser-Meyer-Olkin Measure of Sampling Adequacy is 0.923 while the p – value of the Bartlett's Test of Sphericity is 0.000.

Table 5.10b: Communalities of Analysis of Perceptions on the Effects of Climate Change on Energy Need

	Initial	Extraction
Energy need in buildings in Enugu metropolis varied over the last three decades.	1.000	.934
The variation in energy needs of buildings in Enugu is a product of climate variations	1.000	.897
Does temperature change/increase affect the energy need of a building?	1.000	.941
Does amount and intensity of rainfall affect the energy need of a building?	1.000	.948
Does wind direction affect the energy need of a building?	1.000	.922
Does Humidity and Cloud Cover affect the energy need of a building?	1.000	.928
Does sunshine intensity affect the energy need of a building?	1.000	.913
Heating up of the building increases the energy need in building	1.000	.948
Cooling down of the building increases the energy need in building	1.000	.944

Extraction Method: Principal Component Analysis.

Table 5.10c: Total Variance Explained Analysis of Perceptions on the effects of climate change on the cost of construction and Maintenance

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.375	93.054	93.054	8.375	93.054	93.054
2	.193	2.142	95.196			
3	.124	1.383	96.579			
4	.087	.961	97.540			
5	.077	.857	98.396			
6	.059	.652	99.048			
7	.046	.512	99.560			
8	.024	.270	99.830			
9	.015	.170	100.000			

Extraction Method: Principal Component Analysis.

We can see that the total variance explained is 93.054 percent of variability in the data of the respondents on their perceptions on the effects of climate change on the cost of construction and maintenance.

Table 5.10d: Component Matrix Analysis of Perceptions on the effects of climate change on the cost of construction and Maintenance

	Component
	1
Energy need in buildings in Enugu metropolis varied over the last three decades.	.967
The variation in energy needs of buildings in Enugu is a product of climate variations	.947
Does temperature change/increase affect the energy need of a building?	.970
Does amount and intensity of rainfall affect the energy need of a building?	.973
Does wind direction affect the energy need of a building?	.960
Does Humidity and Cloud Cover affect the energy need of a building?	.963
Does sunshine intensity affect the energy need of a building?	.955
Heating up of the building increases the energy need in building	.974
Cooling down of the building increases the energy need in building	.972

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

The principal component is strongly correlated with all the original variables. That is, only principal component increases with increasing.

This component can be viewed as a measure of the quality of these variables;

1. Heating up of the building increases the energy need in building,

2. Does amount and intensity of rainfall affect the energy need of a building,

3. Cooling down of the building increases the energy need in building,

4. Does temperature change/increase affect the energy need of a building,

5. Energy need in buildings in Enugu metropolis varied over the last three decades,

6. Does Humidity and Cloud Cover affect the energy need of a building,

7. Does wind direction affect the energy need of a building,

8. Does sunshine intensity affect the energy need of a building, and

9. The variation in energy needs of buildings in Enugu is a product of climate variations.

This component can be viewed as a measure of increases the energy need in building as the heating up in the building takes place.

Furthermore, in order to establish a relationship between climate variation over time and variation in building design, construction cost, material and maintenance cost, multiple regression model were developed. Data on majority of the socioeconomic variables capable of defining building designs, cost of construction and maintenance and energy are not easily obtainable and also were not readily available except for building collapse.

Building collapse will be used as a surrogate for possible consequence of climatic factors on cost of construction while other remaining surrogate data for energy needs, maintenance and building designs were elicited from the respondents. Data on building collapse were obtained from government agencies such as NEMA and ECTDA. The respondents were asked at what times of the year they think that they spend more to take care of their energy needs. They were also asked to identify the different times during which they think their building performed poorly due its design in protecting them against climatic influences. The outcomes of the responses and data on collapse collected are shown in table 5.19.

5.2 Summary of Personal Interviews

From the personal interview conducted, the respondents revealed that there are effects of climate change in Enugu and the degree depends on location. While some are exposed to flood, others are affected by strong winds. One of the devastating impact is building collapse. They also pointed out that this effect has increased in the last five decades causing a rise in the cost of construction, building materials used, energy need in building as well as maintenance cost. Only two of the respondents argued that the changes they experience are normal. And that everything in life changes so also building design, cost of construction and maintenance.

5.3 Field Observation

In this research, some sites visited revealed devastating effects of climate change in the environment. Some of the cases are shown below. The heaviness of rainfall experienced in Enugu leads to flood which eventually causes erosion as in plate 5.1, plate 5.2 also shows a church which was flooded at the peak of raining season after a heavy down pour. This is a regular occurrence at such periods. Plate 5.3 shows a major road in Enugu South flooded and movements obstructed, this is seen not just in an area but experienced in most areas of Enugu Urban Area, which an ugly sight and situation. Plate 5.4 is another incidence of flood after rainfall. Plate 5.5 shows wall with flaked paints as a result wind driven rain. There are cases of collapse which occurred after heavy rainfall accompanied by strong wind.

Plate 5.1: Erosion as a result of flooding.

Plate 5:2 A church building flooded on Sunday morning

Plate 5.3: Flood at one of the major roads after a heavy rainfall.

Plate 5.4: A flooded street after a heavy rainfall.

Plate 5.5: Wall paints flaking as a result of wind driven rain.

Plate 5.6: A collapsed building in Enugu Metropolis that resulted after rainfall

Plate 5.7: Building collapse in the study area

Plate 5.7: A building flood in Enugu South LGA

5.4 Summary of Findings

1. The trend plot of temperature variation between1970-2017 is positive as seen in fig. 5.2. This means that temperature is rising. The correlation coefficient r = 0.122 was found not to be statistically significant.

2. The difference between the maximum and minimum temperature in Enugu metropolis is greatly reducing as seen in fig. 5.5. This has a wide range of physiological implication and confirms that Enugu is becoming a heat Island.

3. The rainfall data obtained from NiMet showed that the movement of the time series is sporadic, this is seen in fig. 5.6. the trend plot of rainfall is not statistically significant. A decrease in the annual rate was seen. The mean annual rainfall for the study period is 1765.4mm.

4. The trend plot of relative humidity shown in fig. 5.8 was found not to be statistically significant given the coefficient of 0.055 at 0.05 level of confidence. This evidently reveals that relative humidity is reducing at an annual rate.

5. The relative humidity of Enugu is as a result of increase in temperature pattern and this was also found to be so considering a slight decrease in the annual rainfall in fig. 5.7.

6. The lickert table with a cluster mean value of 4.01 > 3.0 and associated standard deviation of 0.65 indicates that the respondents perceived climate change as contributing to changes in building designs.

7. The result in table 5.3 shows that there are stages in the design of buildings whereby climate parameters are considered and affects important decision regarding the supposed building.

8. The cluster mean value of 3.9 and the associated standard deviation of 0.65 indicates that there are reasons for variations in the cost of construction and maintenance of buildings as seen table 5.4. The most contributing parameter is rainfall.

9. The respondents acknowledged that the evolving new building materials and the transition from Zinc roofing sheet to long aluminum roofing sheet, then to metro tiles and presently stone coated roofing system are all attempts on climate change adaptation as seen in table 5.5.

10. The result according to table 5.5 also shows that the evolving building materials and technologies are good and very functional, but, they would fail the aim of their invention and as such become dysfunctional despite their expensive nature if they are not tailored to adapt to the tropical environment.

11. Table 5.6 shows that wind determines the level of energy need. Cost in energy consumption could be greatly reduced if changing or varying climatic conditions of the concerned sites are put into proper consideration.

12. Poisson regression of cost of energy, cost of construction and maintenance and building design against rainfall, sunshine intensity, maximum temperature, minimum temperature, relative humidity and effective rainfall were shown in equation 5.1, 5.2 and 5.3 respectively.

13. From objective one, the trend analysis of the climate parameters showed that there has been variations in the climate parameters over the assessment period in the study area.

14. The result the test of hypothesis two showed a p – value of 0.001, less than 0.05. The implication is that the overall (cluster) weighted mean of the respondents is significantly above 3.0; (that is 4.0 > 3.0, with a p – value of 0.001). This implies that based on the responses of the respondents, climate contributes significantly to changes in building design at 0.05 level of significance.

15. The result of the test of hypothesis three on one sample T – Test showed that the responses of the respondents are significant. This is because the p – value of 0.003 was gotten; more so, the overall (cluster) weighted mean is 3.9 which is above 3.0. This means that according to the respondents, climate significantly affects the cost of construction and maintenance at 0.05 significance level.

16. It was found from the One Sample T–Test of hypothesis four that climate significantly impacted the construction materials used; that is the issues raised in the questionnaire are significant climate impacts on the construction materials used. This is because the p –value of the One Sample T–Test is 0.003, less than 0.05; with an overall mean of 3.5667>3.0.

17. The result of hypothesis five on one sample T–Test above showed that the questions asked the respondents are significant climate impacts on energy needs. This is because the p – value is 0.000 which is less than 0.05, the overall (cluster) mean being 3.7444>3.0.

5.5 Discussions

Buildings are designed to have at least a minimum resistance to the loads that act on the structure, and on building parts such as roofs and cladding. These loads are partially determined by climate effects. As the climate changes, there is a danger that current building designs will not be suitable for the new climate as well as the resistance in the existing building stock. The types of stresses experienced by buildings vary with climatic environment of their locations. Stresses arise from electrical storms, exposure to driving rain, excessive precipitation, floods and poor drainage and excessive wind speed (Ayoade, 2012).These climatic actions on buildings – such as wind, temperature, rain and solar radiation - have intensities that vary in time. Increasing the lifetime of a structure therefore increases the probability that, in a given time frame, the intensity of one of these actions will exceed the value assumed in the design. Studies (such as Ayoade, 2012; Ezenwaji, Nzoiwu and Umeogu, 2017) have reported that there are four aspects of building for which knowledge of climate is invaluable:

1. The planning and design of a building
2. The actual construction of a building
3. The maintenance of the building after construction
4. The maintenance of comfortable indoor microclimate

From the result, this study underscores the important linkages between changes in climatic parameters of rainfall, temperature, relative humidity etc. and how these changes propagate through effects on building designs, cost of construction of buildings and maintenance, materials and energy needs in buildings. It was observed, based on the trend plots for temperature, rainfall and relative humidity that these climatic variables are changing.

The general air temperature as wells as the minimum temperature are shown to be increasing, while rainfall and relative humidity are experiencing slight decline in annual values. For the study period, it is equally shown that the temperature range is reducing having experienced a reduction of 0.5^{o}C. Thus, has serious implications for physiological comfort of residents as well as on increasing energy needs and costs incurred in providing this. Based on the responses, it was clear that they are quite aware of the contributions of climate change to the observed changes in building designs in the study area. The respondents agreed that these changes in the designs of buildings in Enugu metropolis manifest in the obvious changes in openings in these buildings such as in the designs of windows, doors etc. Similarly, for the consideration of climatic parameters in building designs, all the respondents agreed that this is a possibility in the study area. This follows from the fact that in one way or the other, the persons involved in construction would make decisions regarding the positions of the building, positioning of openings such as windows and doors to ensure maximum illumination of the indoors of such buildings by sunshine during the day while trying to maintain maximum ventilation. On the other hand, a great number of the respondents were of the view that changing climatic conditions, were not responsible for increasing cost of construction. Conversely, they believed that the climate parameters have caused deteriorations in buildings and reducing the life span of these buildings.

Thus, their responses showed that because of this, there is rising cost of maintenance on these buildings. For instance, paints on buildings are easily destroyed due to the impact of wind driven rains. Regarding changes in construction materials, the responses revealed majority of them perceived that the changing construction materials were targeted at adapting buildings to the possible impacts of a changing climate. They acknowledged that though these materials are changing and sometimes expensive but that they are not good enough if climate is not considered in their development. The result also shows that though the newly evolving building materials and technologies care good and are very functional, they would fail the aim of their invention and as such still become dysfunctional despite their expensive nature if they are not tailored to adapt to the tropical environment which is characterized by excessive rainfall impacts, high temperatures and humidity etc.; they may be easily waterlogged or penetrated during rainfall.

Furthermore, the relationships amongst the perceived effects of climate variables on buildings were sought. The result showed a high level of associations between some responses as well as serial autocorrelation as many of the perceived effects show strong and significant positive correlation with each order. With these very serious autocorrelations that characterize the data, there was no other alternative than to subject the correlation results to PCA. This was needed in order to highlight the most dominant effects of climate on buildings in Enugu. The PCA analysis collapsed the nine responses on various effects of climate variations on building designs, cost of construction and maintenance, materials and energy needs into significant and orthogonal components that can explain the variables in the observed data while the primacy of two components manifested for each.

However, from the PCA analysis, the following assertions are made

1. As regards building designs, that:
    a. Building Designs in Enugu Urban Area has changed over time
    b. Climate conditioning is driving the changes in building designs in Enugu.
2. For construction cost and maintenance of buildings in Enugu:
    a. Changing climatic variables and their impacts on buildings are increasing the cost of maintenance
    b. Cost of construction and maintenance of buildings has generally increased in Enugu.
3. On materials for construction:
    a. New building materials said to be climate tolerant are now being utilized in construction of buildings.
    b. Building materials are changing due to changing climate situations while these newly adopted construction materials are still expensive.
4. For energy needs:
    a. Variations in energy needs is a consequence of changes in the character of indoor microclimatic parameters
    b. Changes in energy needs are as a result of changes in the characteristics of climatic variables.

In addition, in the bid to establish a relationship between climate variation over time and variation in building design, construction cost, material and maintenance cost, multiple regression models were developed. Based on the data generated from the respondents on different times during which they think their building performed poorly due its design in protecting them against climatic influences as wells as the impacts on cost of construction, maintenance and energy cost. The significance of the regression equations were tested by means of analysis of variance test.

The result showed that there is no significant relationship between climate variation and variations in building design, construction cost, material and maintenance cost. At 0.05 level of confidence, the critical value of F from SNEDECOR's table is 4.12. For building design, since F of 0.489 < 4.12, the H_o is accepted. For construction cost, F of 1.109<4.12 shows that H_o is accepted; for energy needs, F of 5.809>4.12, H_o is rejected and for cost of maintenence, F of 1.539 < 4.12 implies that H_o is accepted Thus, there is a no significant relationship between the design of buildings, cost of maintennace and cost of construction and the seven independent meteorological variables. On other hand, H_o was rejected for energy needs and as a result H_1 is posited as: there is a significant relationship between energy needs in buildings and the seven independent meteorological variables. This outcome shed light on the fact that some the result of the relationship analysis agrees with outcome of the t test statistics on the perceived response of the respondents on energy needs whuile it varies with others.

However, for the impact of climate variability and change on structural safety, the changes in the following climatic actions on buildings need to be evaluated namely: wind load, temperature load and water accumulation due to heavy and excessive rain. Based on this, the buildings erected within the study area are subject to these climatic conditions and influences which they must withstand. For example, due to urbanization, Enugu is becoming a tree-less urban center and as a consequence, driving-rain can be a problem. This leads to rain penetration in buildings. Ayoade (2012), quoted that rain penetration values in excess of 100 are undesirable and indicates that such buildings need some kind of water proofing. The degree of rain penetration in a building is calculated as follows:

$$\boldsymbol{P = rV^2}$$

Where, r is the maximum rainfall in mm in five minutes and V is the wind speed in meters per second at the time of the occurrence of the rainfall.

Furthermore, the nature of penetrating or driving rain was calculated for the Enugu urban area based on a daily rainfall and wind speed data collected from NIMET. A maximum rainfall amount

(r) of 7.2mm was measured on 17th September, 2016 with a wind speed (V) of 5.1m/s measured at same time; the driving rain penetration is determined as follows:

$$\mathbf{P = 7.2 \times (5.1)^2}$$

$$\mathbf{P = 187.3}$$

This result implies that majority of buildings in Enugu are exposed to the penetrating impact of rain. Consequently, in a changing climate with increasing urbanization leading to land cover changes that tends towards artificial synthetic surfaces with less available trees, more buildings will be exposed to the driving rain impact due to less availability of wind breaks. These buildings needs some form of weather proofing such as in the use of overhangs (Ezenwaji, Nzoiwu and Umeogu, 2017).

Equally, with this scenario, it is expected that the life span of these structures will be affected while at the same time increasing the cost of maintenance of such buildings. This follows the fact that dampness is a problem in humid climates where the overhangs of a building fail to shelter the walls from rain penetration or where there are no overhangs at all. Dampness may also affect the floor and walls of a building erected on sites that are characterized by high penetrating rain impact. This was succinctly emphasized in Agboola (2011). He clearly stated that in order to ensure effective design solution, the various climatic zones in Nigeria needs to be properly understood and incorporated into the architectural designs of buildings in these zones. For the warm humid region of southern Nigeria, which Enugu is part of, Agboola (2011) reported that ensuring effective design solution in this zone requires the use of high pitched roofs with wide roof overhangs of buildings facilitating quick rainwater disposal and protect the exterior house walls from brunt of rainfall. Other documented sources such as Windapo and Rotimi (2012), Ayininuola and Olalusi (2004) corroborates these. For example, these studies noted that the reasons for structural failures are due to limited knowledge of building structural behavior and unanticipated environmental phenomena. For unanticipated environmental phenomena, rainfall was acknowledged as part of causes of building collapse

Furthermore, climate and some other factors such as available technology and materials have greatly influenced housing types in various parts of the world (Ayoade, 2012). The structures built by local inhabitants are largely adapted to their climatic environment. In modern times, improvement in technology and cross-cultural contacts now determine the architecture and form of buildings globally. Although such buildings are elegant and modern, they are expensive to maintain and run most of the time. Their indoor microclimates are artificially created by the use of fans, air conditioners and humidifiers at great cost. These artificial gadgets have high carbon footprint that is unacceptable in this era of global warming. This is a major factor in the increasing energy consumption of cities in the world today (Ayoade, 2012). Suitable indoor climate in buildings can be partly achieved at less cost through proper design that will ensure adequate ventilation and through the wise choice of building materials. Similar position was clearly supported in the study by Plant, Longmore and Hopkinson (2002).They stressed that, as reagrds indoor comfort level, which most often determines the level of energy needs, the following design factors must be taken into account in order to use daylight to an advantage: variations in the amount and directions of the incident daylight, luminance (photometric, brightness) and luminance contribution of colour, partly cloudy and over cast skies and variation in sunlight intensity and direction.

Temperature is undoubtedly the most important element of the microclimate within a building. The response of the human body to air temperature and hence his perception of comfort is moderated by the effects of air movement and humidity. In the tropics, the main purpose of air conditioning is to reduce effective temperature. The effective temperature of any place is of great importance to heating and ventilating engineers. The effective temperature index is defined as the temperature in which motionless saturated air would induce in a sedentary worker wearing ordinary indoor clothing the same sensation of comfort as that induced by the actual conditions of temperature, humidity and air movement. A good approximation of the effective temperature is given by the empirical equation:

$$ET = 0.4(T_d + T_w) + 4.8°C$$

Where ET is the effective temperature, Td and Tw are dry and wet bulb temperatures in ^oC respectively. The equation is sometimes called the discomfort index.

This was calculated for Enugu for a period of 47 years in order to determine the effective temperature and the tendency of increase in cost of building, maintenance and energy use. The graph of mean annual effective temperature (fig 5.9) showed that this has been increasing overtime.

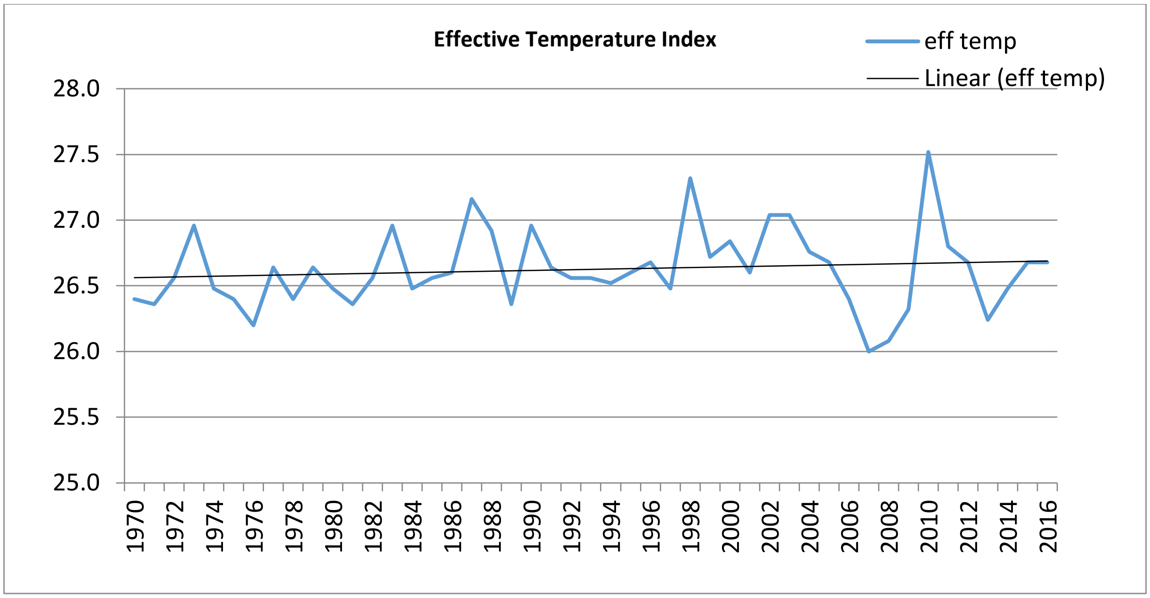

Fig 5.9: The graph of mean annual effective temperature

This was expected given the climate characteristics of Enugu replicated in the nature of temperature, relative humidity and rainfall trend. The mean effective temperature for Enugu is calculated as 26.6^{o}C. Based on a series of experiments conducted by researchers (e.g. Houghten and Yaglou, 1923), this index has been used variously to define the comfort zones of countries. In Nigeria (table 5.1), Peel (1961) in Ayoade (2012) reported that the effective temperature comfort zone of Nigeria ranges from 18 – 21^{o}C. The implication of this is that when the effective temperature is below 21^{o}C, no discomfort is experienced. As the value of the index rises above 21^{o}C, an increasing number of people become uncomfortable while getting to 24^{o}C and about 26^{o}C, virtually everybody will be uncomfortable.

More so, the nature of effective temperature and the discomfort index in Enugu is high and based on fig 5.9, the trajectory is positive and expected to continue rising in a warming climate; consequently, the outcome of this is that there will be increasing to for artificial gadgets such as fans, air conditioners and humidifiers in buildings across the Enugu city. With this outcome is also increasing energy bill and cost of maintenance as these gadgets need to be serviced frequently for optimum performance thereby increasing the overall maintenance cost of these buildings. In the same vein, the quantity of heat which the atmosphere is capable of absorbing in an hour from an exposed surface of 1m was calculated. This is called the wind-chill index developed by Simple and Passel (1945). This was calculated using the formula:

$$K_o = \left(10.45 + 10\sqrt{V} - V\right)(33 - T)$$

Where, K_o, the wind chill index, is the heat loss in kcal $m^{2-}hr^{-1}$, v is the wind speed in m/s and T is the air temperature in ^{o}C.

The wind chill index, as calculated, yielded values slightly below 100 for some years and slightly above 100 for other years. This result showed that the wind-chill is warm and has remained so. Thus, the expected cooling through the process of latent heat of vaporization is reduced due to the low convective drying power of the atmosphere associated with increasing ambient temperature. This is a further confirmation of climate influence on cost of energy as depicted earlier. Consequently, people will tend to spend more money on energy trying to maintain the indoor temperature in order to feel comfortable.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMEDATION

6.1 Summary and Conclusion

This study has assessed the effects of climate variability and change on aspects of the building industry in Enugu metropolis. Questionnaires were administered to the respondents to elicit information on these. Based on the outcome of the research, there is agreement between the perceptions of the respondents on the nature of climate change effects on variations in the energy needs in buildings in Enugu and the established relationship given by the regressive model. There is also agreement on the part of the respondents that climate variabilities has impacted on the changing designs of buildings as well as varying degrees of impacts on cost of maintenance and changes in construction materials. It was revealed in the study, as proven by the responses given by the respondents, that as temperature conditions of Enugu is rising gradually, which has also been typified in Enete (2015) as a heat island, and concomitant decreases in relative humidity and rainfall amounts, that there is tendency of increasing energy cost as people struggle these days to maintain tolerable indoor microclimate and reduce physiological stress.

In further attempt to know the main perceived effects due to climate variations and change confronting investigated aspects of building, a principal component analysis was performed to simplify the relationship between large bodies of variables and was able to collapse the responses extracted from the respondents into significant and orthogonal components that explained the variables in the observed data. When the PCA was transformed, it revealed a number of realities:

a. Building Designs in Enugu metropolis has changed over time as seen in table 5.3.

b. Climate conditioning is driving the changes in building designs in Enugu.

c. Table 5.4 reveals that changing climatic variables and their impacts on buildings are increasing the cost of maintenance.

d. Cost of construction of buildings has generally increased in Enugu as seen in table 5.4.

e. Table 5.5 reveal new building materials said to be climate tolerant are now being utilized in construction of buildings.

f. Building materials are changing due to changing climate situations while these newly adopted construction materials are still expensive.

g. From table 5.6, variation in energy needs is a consequence of changes in the character of indoor microclimatic parameters.

h. Changes in energy needs are as a result of changes in the characteristics of climatic variables.

This study and other similar studies reviewed in this work represent a growing body of literatures that propagates the challenging effects of potential climate change and variations on different aspects of building and as perceived by the respondents in Enugu metropolis. It must be acknowledged that these would persist as long as the burden of climate effects due to changing climatic conditions remains and when not enough efforts are being made to adapt buildings to the changing environmental conditions and if appropriate modifications are not made in the building code of the country. This position was emphasized in the study by Agboola (2011). Thus the need to introduce a workable and sustainable legislations guiding building practices in a climate changing world. The need for this is becoming increasingly important in the face of mounting effects of climate change in this sector.

There is need for ensuring building sustainability which advocates for sustainable construction. This was the main emphasis of the study made in 2012 by Windapo and Rotimi.

However, Sev (2009) noted that sustainable construction can be differentiated according to the three dimensions of sustainable development (environmental, social and economic) and must rely on three basic principles namely:

1. Resource management;
2. life-cycle design;
3. And design for human habitation.

Resource management yields specific design methods through the selection of durable materials (Sev, 2009) that could extend service lives of buildings components, thus reducing material consumption. Durable materials would also require less maintenance, reduce operating budgets (Kim and Rigdon, 1998) and ultimately reduce the potential for building failure.

The life-cycle design of a building during pre-building, building and post-building phases seek to balance environmental concerns with traditional issues that always affect decisions and choices made at the design phase (Sev, 2009). During the pre-building phase, appropriate site selection helps in the determination of the degree of resource use and the disturbance of existing and natural systems that will be required to support a development project (Dines, 1996). Appropriate site selection also incorporates site planning whereby the forms and orientation of the buildings are appropriately considered. The sustainable design element of a building's life-cycle affords significant opportunities for influencing project sustainability before construction operations begin on site (Vanegas, 2003) such as in considering the prevailing environmental and climatic conditions which could be used to minimize climatic impact later on.

Human needs for safety, health, physiological comfort, physiological satisfaction and productivity, must be balanced with the carrying capacity of the natural and cultural environments by a sustainable construction industry, considering that more than 70% of people's time are spent indoors (Sev, 2009). All building systems and equipment need to be commissioned in accordance to specified climatic and environmental factors. When this is not considered, it could have a direct negative impact on the productivity of the buildings' occupants (Adenubi and Windapo, 2007).

6.2 Contribution to Knowledge

1. The research developed an understanding of how climate change affects construction cost, building design, building materials, energy need and maintenance cost.

2. A trend analysis of the rate of change in climate variables in the past five decades (1970-2016) in Enugu metropolis as it relates to building design, construction cost, building material, energy need was established.

3. A regression model was generated showing the mathematical relationship between: cost of construction and maintenance, building design, energy need and building materials and the independent variables (Rainfall, Sunshine Intensity, Temperature, effective rainfall wind speed and Relative Humidity).

i. Poisson Regression of Cost of Energy (as dependent variable) against Rn, SI, Tmax, Ws, Tmin, Rh and Eff. Rn: $\eta_i = -0.01650X_1 - 0.41782X_2 + 0.02075X_7$ (5.1)

ii. Poisson Regression of Cost of Maintenance (as dependent variable) against Rn, SI, Tmax, Ws, Tmin, Rh and Eff. Rn: $\eta_i = -11.011463 - 0.008974X_1 + 0.697005X_3 + 0.536338X_4 - 0.893465X_5 + 0.129563X_6 + 0.021145X_7$. (5.2)

iii. Poisson Regression of Building Design Performance (as dependent variable) against Rn, SI, Tmax, Ws, Tmin, Rh and Eff. Rn: $\eta_i = 0.571588X_4$. (5.3)

6.3 Recommendations

Based on the foregoing, the following recommendations are made:

1. There is need for building professionals to obtain basic climatic data from meteorological stations nearer to their proposed site and analyze such data for proper design of buildings.
2. Climatic site analysis should be carried out which will provide design guidelines for layout, orientation, spacing, cross ventilation, treatment of spaces between buildings, shade trees, courtyards, shape and height of the buildings as well as house form. The site climate deals with ground cover and the topography which differs from that obtained from the meteorological stations.
3. We need to modify our new architecture to conform to the prevalent standards. In this way, we should start to erect buildings that are in tune with the local climates either in terms of architecture or materials used.
4. Rainfall especially the wind driven rain should specifically be singled out for proper consideration during design and building in the urban areas of Enugu State.
5. There is need for use of overhangs in building located within Enugu and environs to minimize the impacts of wind driven rain on the exterior of buildings. Thus, for buildings without this, landlords and house owners should install overhangs over openings like windows and doors.

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APPENDIX 1

QUESTIONNAIRE

Dear Respondent,

This Questionnaire is very important aspect of an ongoing Ph.D. dissertation on

"Analysis of effects of climate change on Buildings in Enugu" Questionnaire facilitates the collection of data for analysis. This research work is being carried out in the department of Building, Environmental sciences, Nnamdi Azikiwe University Awka. Sequel to this, I want to generate data through this questionnaire to enable me complete the research work.

Please assist me by providing candid answers to the following questions to the best of your knowledge. Be rest assured that your responses will be handled as confidential and will only be used for academic purposes.

Thanks for your understanding.

Iheama N. B.

2013287003

Ph.D. Student.

(Please indicate by ticking the most appropriate box to indicate your answer)

Section A: Personal Information

1	**WHAT IS YOUR AGE BRACKET?**	**INDICATE**
	25 – 35	
	36 – 45	
	46 – 59	
	60 and above	
2	**WHAT IS YOUR GENDER?**	
	Female	
	Male	
3	**HOW LONG HAVE YOU BEEN IN ENUGU?**	
	Less than 5year	
	6-10years	
	11-20years	
	21-30years	
	31years and above	
4	**WHAT IS YOUR RESIDENTIAL STATUS IN ENUGU?**	
	House Owner / Landlord	
	Tenant	
	Family House Occupant or Attachment Occupant	
5	**WHAT IS YOUR OCCUPATION?**	
	Civil/Structural Engineer	
	Builder	
	Architect	
	Quantity Surveyors	
	Others Specify: ……………………………………………	
6	**WHAT IS YOUR HIGHEST ACADEMICAL QUALIFICATION?**	
	HND	
	B.Sc.	
	M.Sc.	
	Ph.D.	
	Others Specify: ……………………………………………	

For Sections B-F, Tick (✓) the option that best represent your opinion of the statement made.

Keys: 5 = Strongly Agree

4 = Agree

3 = No Opinion / No Idea

2 = Disagree

1 = Strongly Disagree

SECTION B: IMPACTS OF CLIMATE CHANGE ON BUILDING DESIGN FOR THE LAST THREE DECADES

S/N	**EFFECTS**	5(SA)	4(A)	3(NI)	2(D)	1(SD)
1	Building Designs has greatly changed over the last three decades.					
2	Roofing Patterns has greatly changed over the last three decades.					
3	There has been a continuous evolution of new window designs over the last three decades.					
4	The change in building design is a product of technological innovation only and has no link with changes in the climate parameters.					
5	The change in building designs is a product of technological innovation aimed at containing environmental conditions and climate change.					
6	Building patterns in Enugu Metropolis changed over the last three decades due to climate change.					
7	It is very important to consider climatic parameters in the area when designing a building.					
8	Climate parameters are the main factors considered in window designs and ventilation in building.					
9	The emergence of new designs of building like more high rise, cemented/synthetic surfaces etc, has environmental implications which can only be addressed by critically considering climatic factors.					

SECTION C: EFFECTS OF CLIMATE CHANGE ON THE COST OF BUILDING CONSTRUCTION AND MAINTENANCE FOR THE LAST THREE DECADES

	EEFFECTS	5(SA)	4(A)	3(NI)	2(D)	1(SD)
1	The cost of building construction has increased over the last three decades.					
2	The cost of building maintenance has also increased over the last three decades.					
3	The increase in the cost of building construction and maintenance is as a result of the present day economic recession only.					
4	Climate change has affected the cost of building construction.					
5	Climate change has caused some buildings to be deteriorated, renovated or/and amended without living out their life span					
6	Climate Change is the cause of changes in building color and fading of paints shortly after construction, which have cost implications.					
7	High rainfall affects the cost of building construction and maintenance:					
8	Very high temperatures affects the cost of building construction and maintenance					
9	Strong wind affects the cost of building construction and maintenance					

SECTION D: EFFECTS OF CLIMATE CHANGE ON THE TYPE OF MATERIAL USED IN BUILDING CONSTRUCTION OVER THE LAST THREE DECADES

S/N	EEFFECTS	5(SA)	4(A)	3(NI)	2(D)	1(SD)
1	The materials used for building construction have changed over the last three decades.					
2	The newly evolving building materials are more climate compliant and lasts longer.					
3	The new designs and types building materials are more expensive and requires higher technology.					
4	The new technologies in building materials are only beautiful without any consideration of climatic variables.					
5	The transition from ordinary Zinc to Aluminum and to Metro-coppa, metro tiles and Stone Coated type of roofing is of climate change adaptation essence.					
6	Green roofing is adopted to contain the impacts of climate change					
7	Hydro foam is adopted to contain the impacts of climate change					
8	Natural Bricks is adopted to contain the impacts of climate change					
9	Stone coated roofing is adopted to contain the impacts of climate change					

SECTION E: EFFECTS OF CLIMATE CHANGE ON THE ENERGY NEED IN BUILDINGS OVER THE LAST THREE DECADES

	EEFFECTS	5(SA)	4(A)	3(NI)	2(D)	1(SD)
1	Energy need in buildings in Enugu metropolis varied over the last three decades.					
2	The variation in energy needs of buildings in Enugu is a product of climate change.					
3	Does temperature change/increase affect the energy need of a building?					
4	Does amount and intensity of rainfall affect the energy need of a building?					
5	Does wind direction affect the energy need of a building?					
6	Does Humidity and Cloud Cover affect the energy need of a building?					
7	Does sunshine intensity affect the energy need of a building?					
8	Heating up of the building increases the energy need in building					
9	Cooling down of the building increases the energy need in building					

SECTION F:

1. IN WHAT OTHER WAY(S) DO YOU THINK CLIMATE CHANGE HAS AFFECTED BUILDING?

APPENDIX 2

LIST OF QUESTIONS FOR PERSONAL INTERVIEWS.

1. How long have you lived in Enugu?
2. Do you think the climate of Enugu has changed over the last three decades?
3. Are you a landlord or a tenant?
4. When was your house built?
5. To what extent do you think that the cost of building houses in your area has increased over the last three decades? (say: 2times, 3times, 5times, 10 times and above)
6. Do you think that some of the materials you used in building your house are obsolete now?
7. Do you prefer some of the recent building materials (like the new roofing sheets, new windows, green roofs, new ceiling materials) to the old types or you prefer the old ones? What are your reasons for the preference?
8. If you have the resources would you like to renovate or reconstruct your house to make it more comfortable?
9. Are you more comfortable in your house in this area some years back than now or there is no difference? You may use a parameter deficiency or efficiency to cite an instance.
10. Do change in temperature, rainfall and other climatic elements in your location affect your building in any way?
11. Rate your level of satisfaction or comfort in your house. (say: Very comfortable, comfortable, manageable, bad, or very bad).
12. How does the climate of your environment affect your comfort level?
13. Do you think there are some modifications your house may need due to climatic factors to make it more comfortable?
14. What can you say about the energy need in your building, are you able to cope with natural response in energy?
15. At what time of the year do you think climate change affects the following:

    a. Building Design

    b. construction cost

    c. maintenance cost

    d. Building energy need

    e. Building Materials.

APPENDIX 3

T-Test

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Climate Contribution to Changes in Building Design	9	4.0000	.59161	.19720

One-Sample Test

	Test Value = 3.0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Climate Contribution to Changes in Building Design	5.071	8	.001	1.00000	.5452	1.4548

T-Test

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Perceptions on Climate effects on the cost of construction and maintenance	9	3.9000	.64614	.21538

One-Sample Test

	Test Value = 3.0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Perceptions on Climate effects on the cost of construction and maintenance	4.179	8	.003	.90000	.4033	1.3967

T-Test

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Perceptions on Climate impacts on Construction Materials Used	9	3.5667	.39370	.13123

One-Sample Test

	Test Value = 3.0					
					95% Confidence Interval of the Difference	
	t	Df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Perceptions on Climate impacts on Construction Materials Used	4.318	8	.003	.56667	.2640	.8693

T-Test

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Perceptions on Climate impacts on Energy Needs	9	3.7444	.32059	.10686

One-Sample Test

	Test Value = 3.0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Perceptions on Climate impacts on Energy Needs	6.966	8	.000	.74444	.4980	.9909

APPENDIX 4

OUTPUT OF POISSON REGRESSION

```
R version 3.4.0 (2017-04-21) -- "You Stupid Darkness"
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Platform: i386-w64-mingw32/i386 (32-bit)

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> No.of.Building.Collapse=c(0,0,2,0,2,3,1,1,2,1,0,0)
> Cost.of.Energy=c(33,46,39,34,13,13,19,37,11,20,27,33)
> Cost.of.Maintenance=c(11,16,37,29,35,31,41,27,17,41,13,27)
> Building.Design.Performance=c(33,21,19,22,15,51,43,19,29,27,17,30)
> Rn=c(11.7,18.0,67.9,148.2,236.2,260.7,247.1,219.8,296.9,213.9,27.4,7.4)
> SI=c(6.1,6.2,5.8,6.1,6.0,5.1,3.7,3.5,4.1,5.4,7.0,6.8)
> Tmax=c(33.4,34.8,34.6,33.4,31.8,30.5,29.4,29.2,29.9,30.9,32.5,33.0)
> Ws=c(5.7,5.7,6.3,6.0,5.2,5.2,5.4,5.4,4.8,4.5,4.2,5.0)
> Tmin=c(21.0,22.7,23.9,23.7,23.0,22.4,22.2,22.2,22.1,22.0,21.8,20.1)
```

```
> Rh=c(54.9,60.8,68.3,74.5,79.4,81.8,83.1,83.4,83.3,80.8,72.7,61.3)
> Eff.Rn=c(11.5,17.5,60.5,113.1,146.9,151.1,149.4,142.5,154.7,140.7,26.2,7.3)
> data1=data.frame(No.of.Building.Collapse,Rn,SI,Tmax,Ws,Tmin,Rh,Eff.Rn)
> data1
   No.of.Building.Collapse    Rn  SI Tmax  Ws Tmin   Rh Eff.Rn
1                        0  11.7 6.1 33.4 5.7 21.0 54.9   11.5
2                        0  18.0 6.2 34.8 5.7 22.7 60.8   17.5
3                        2  67.9 5.8 34.6 6.3 23.9 68.3   60.5
4                        0 148.2 6.1 33.4 6.0 23.7 74.5  113.1
5                        2 236.2 6.0 31.8 5.2 23.0 79.4  146.9
6                        3 260.7 5.1 30.5 5.2 22.4 81.8  151.1
7                        1 247.1 3.7 29.4 5.4 22.2 83.1  149.4
8                        1 219.8 3.5 29.2 5.4 22.2 83.4  142.5
9                        2 296.9 4.1 29.9 4.8 22.1 83.3  154.7
10                       1 213.9 5.4 30.9 4.5 22.0 80.8  140.7
11                       0  27.4 7.0 32.5 4.2 21.8 72.7   26.2
12                       0   7.4 6.8 33.0 5.0 20.1 61.3    7.3
> data2=data.frame(Cost.of.Energy,Rn,SI,Tmax,Ws,Tmin,Rh,Eff.Rn)
> data2
z
1              33  11.7 6.1 33.4 5.7 21.0 54.9   11.5
2              46  18.0 6.2 34.8 5.7 22.7 60.8   17.5
3              39  67.9 5.8 34.6 6.3 23.9 68.3   60.5
4              34 148.2 6.1 33.4 6.0 23.7 74.5  113.1
5              13 236.2 6.0 31.8 5.2 23.0 79.4  146.9
6              13 260.7 5.1 30.5 5.2 22.4 81.8  151.1
7              19 247.1 3.7 29.4 5.4 22.2 83.1  149.4
8              37 219.8 3.5 29.2 5.4 22.2 83.4  142.5
9              11 296.9 4.1 29.9 4.8 22.1 83.3  154.7
10             20 213.9 5.4 30.9 4.5 22.0 80.8  140.7
```

```
11            27  27.4 7.0 32.5 4.2 21.8 72.7   26.2
12            33   7.4 6.8 33.0 5.0 20.1 61.3    7.3
> data3=data.frame(Cost.of.Maintenance,Rn,SI,Tmax,Ws,Tmin,Rh,Eff.Rn)
> data3
  Cost.of.Maintenance    Rn  SI Tmax  Ws Tmin   Rh Eff.Rn
1                   11  11.7 6.1 33.4 5.7 21.0 54.9   11.5
2                   16  18.0 6.2 34.8 5.7 22.7 60.8   17.5
3                   37  67.9 5.8 34.6 6.3 23.9 68.3   60.5
4                   29 148.2 6.1 33.4 6.0 23.7 74.5  113.1
5                   35 236.2 6.0 31.8 5.2 23.0 79.4  146.9
6                   31 260.7 5.1 30.5 5.2 22.4 81.8  151.1
7                   41 247.1 3.7 29.4 5.4 22.2 83.1  149.4
8                   27 219.8 3.5 29.2 5.4 22.2 83.4  142.5
9                   17 296.9 4.1 29.9 4.8 22.1 83.3  154.7
10                  41 213.9 5.4 30.9 4.5 22.0 80.8  140.7
11                  13  27.4 7.0 32.5 4.2 21.8 72.7   26.2
12                  27   7.4 6.8 33.0 5.0 20.1 61.3    7.3
> data4=data.frame(Building.Design.Performance,Rn,SI,Tmax,Ws,Tmin,Rh,Eff.Rn)
> data4
          Building Des.Perf. Rn   SI Tmax  Ws  Tmin Rh    Eff.Rn
1                   33  11.7 6.1 33.4 5.7 21.0 54.9   11.5
2                   21  18.0 6.2 34.8 5.7 22.7 60.8   17.5
3                   19  67.9 5.8 34.6 6.3 23.9 68.3   60.5
4                   22 148.2 6.1 33.4 6.0 23.7 74.5  113.1
5                   15 236.2 6.0 31.8 5.2 23.0 79.4  146.9
6                   51 260.7 5.1 30.5 5.2 22.4 81.8  151.1
7                   43 247.1 3.7 29.4 5.4 22.2 83.1  149.4
8                   19 219.8 3.5 29.2 5.4 22.2 83.4  142.5
9                   29 296.9 4.1 29.9 4.8 22.1 83.3  154.7
10                  27 213.9 5.4 30.9 4.5 22.0 80.8  140.7
```

```
11                17  27.4 7.0 32.5 4.2 21.8 72.7   26.2
12                30  7.4  6.8 33.0 5.0 20.1 61.3    7.3
>
> str(data1)
'data.frame':   12 obs. of  8 variables:
 $ No.of.Building.Collapse: num  0 0 2 0 2 3 1 1 2 1 ...
 $ Rn                     : num  11.7 18 67.9 148.2 236.2 ...
 $ SI                     : num  6.1 6.2 5.8 6.1 6 5.1 3.7 3.5 4.1 5.4 ...
 $ Tmax                   : num  33.4 34.8 34.6 33.4 31.8 30.5 29.4 29.2 29.9 30.9 ...
 $ Ws                     : num  5.7 5.7 6.3 6 5.2 5.2 5.4 5.4 4.8 4.5 ...
 $ Tmin                   : num  21 22.7 23.9 23.7 23 22.4 22.2 22.2 22.1 22 ...
 $ Rh                     : num  54.9 60.8 68.3 74.5 79.4 81.8 83.1 83.4 83.3 80.8 ...
 $ Eff.Rn                 : num  11.5 17.5 60.5 113.1 146.9 ...
> str(data2)
'data.frame':   12 obs. of  8 variables:
 $ Cost.of.Energy: num  33 46 39 34 13 13 19 37 11 20 ...
 $ Rn            : num  11.7 18 67.9 148.2 236.2 ...
 $ SI            : num  6.1 6.2 5.8 6.1 6 5.1 3.7 3.5 4.1 5.4 ...
 $ Tmax          : num  33.4 34.8 34.6 33.4 31.8 30.5 29.4 29.2 29.9 30.9 ...
 $ Ws            : num  5.7 5.7 6.3 6 5.2 5.2 5.4 5.4 4.8 4.5 ...
 $ Tmin          : num  21 22.7 23.9 23.7 23 22.4 22.2 22.2 22.1 22 ...
 $ Rh            : num  54.9 60.8 68.3 74.5 79.4 81.8 83.1 83.4 83.3 80.8 ...
 $ Eff.Rn        : num  11.5 17.5 60.5 113.1 146.9 ...
> str(data3)
'data.frame':   12 obs. of  8 variables:
 $ Cost.of.Maintenance: num  11 16 37 29 35 31 41 27 17 41 ...
 $ Rn                 : num  11.7 18 67.9 148.2 236.2 ...
 $ SI                 : num  6.1 6.2 5.8 6.1 6 5.1 3.7 3.5 4.1 5.4 ...
 $ Tmax               : num  33.4 34.8 34.6 33.4 31.8 30.5 29.4 29.2 29.9 30.9 ...
 $ Ws                 : num  5.7 5.7 6.3 6 5.2 5.2 5.4 5.4 4.8 4.5 ...
```

```
 $ Tmin              : num  21 22.7 23.9 23.7 23 22.4 22.2 22.2 22.1 22 ...
 $ Rh                : num  54.9 60.8 68.3 74.5 79.4 81.8 83.1 83.4 83.3 80.8 ...
 $ Eff.Rn            : num  11.5 17.5 60.5 113.1 146.9 ...
> str(data4)
'data.frame':   12 obs. of  8 variables:
 $ Building.Design.Performance: num  33 21 19 22 15 51 43 19 29 27 ...
 $ Rn                         : num  11.7 18 67.9 148.2 236.2 ...
 $ SI                         : num  6.1 6.2 5.8 6.1 6 5.1 3.7 3.5 4.1 5.4 ...
 $ Tmax                       : num  33.4 34.8 34.6 33.4 31.8 30.5 29.4 29.2 29.9 30.9 ...
 $ Ws                         : num  5.7 5.7 6.3 6 5.2 5.2 5.4 5.4 4.8 4.5 ...
 $ Tmin                       : num  21 22.7 23.9 23.7 23 22.4 22.2 22.2 22.1 22 ...
 $ Rh                         : num  54.9 60.8 68.3 74.5 79.4 81.8 83.1 83.4 83.3 80.8 ...
 $ Eff.Rn                     : num  11.5 17.5 60.5 113.1 146.9 ...
> mydata1=glm(No.of.Building.Collapse~Rn+SI+Tmax+Ws+Tmin+Rh+Eff.Rn, family =
poisson())
> summary(mydata1)


Call:
glm(formula = No.of.Building.Collapse ~ Rn + SI + Tmax + Ws +
    Tmin + Rh + Eff.Rn, family = poisson())


Deviance Residuals:
      1        2        3        4        5        6        7        8
-0.1595  -0.5375   0.9085  -1.7059   0.1698   0.6694  -0.2783   0.1090
      9       10       11       12
-0.4355   0.4916  -0.5775  -0.2317


Coefficients:
             Estimate Std. Error z value Pr(>|z|)
(Intercept) -45.11843   67.52827  -0.668    0.504
```

```
Rn          0.02084    0.02163   0.964    0.335
SI         -0.01607    1.03666  -0.016    0.988
Tmax        0.61964    2.62816   0.236    0.814
Ws          0.79751    2.87689   0.277    0.782
Tmin        0.09811    3.75265   0.026    0.979
Rh          0.24958    0.67615   0.369    0.712
Eff.Rn     -0.03446    0.06243  -0.552    0.581

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 14.9094  on 11  degrees of freedom
Residual deviance:  5.4345  on  4  degrees of freedom
AIC: 38.267

Number of Fisher Scoring iterations: 6

> mydata2=glm(Cost.of.Energy~Rn+SI+Tmax+Ws+Tmin+Rh+Eff.Rn, family = poisson())
> summary(mydata2)

Call:
glm(formula = Cost.of.Energy ~ Rn + SI + Tmax + Ws + Tmin + Rh +
    Eff.Rn, family = poisson())

Deviance Residuals:
       1         2         3         4         5         6         7         8
-0.42214   0.95386  -1.05602   0.77691  -0.06869   0.15390  -0.80420   0.78456
       9        10        11        12
 0.05343  -0.45514  -0.17548   0.11631
```

```
Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  1.52934    4.33068   0.353  0.72398
Rn          -0.01650    0.00518  -3.186  0.00144 **
SI          -0.41782    0.20059  -2.083  0.03725 *
Tmax         0.20829    0.22989   0.906  0.36491
Ws          -0.02085    0.27899  -0.075  0.94043
Tmin        -0.16488    0.22957  -0.718  0.47263
Rh           0.02126    0.03743   0.568  0.57001
Eff.Rn       0.02075    0.01050   1.976  0.04815 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 58.0594  on 11  degrees of freedom
Residual deviance:  4.3518  on  4  degrees of freedom
AIC: 80.884

Number of Fisher Scoring iterations: 4

> mydata3=glm(Cost.of.Maintenance~Rn+SI+Tmax+Ws+Tmin+Rh+Eff.Rn, family = poisson())
> summary(mydata3)

Call:
glm(formula = Cost.of.Maintenance ~ Rn + SI + Tmax + Ws + Tmin +
    Rh + Eff.Rn, family = poisson())
```

```
Deviance Residuals:
       1         2         3         4         5         6         7         8
-0.34868   0.00490   1.23467  -1.97260   1.03572   0.30571   1.59513  -1.07196
       9        10        11        12
-1.49281   0.43229  -0.26328   0.08503

Coefficients:
             Estimate Std. Error z value Pr(>|z|)
(Intercept) -11.011463   5.740199  -1.918  0.05507 .
Rn           -0.008974   0.003851  -2.331  0.01977 *
SI           -0.215216   0.181035  -1.189  0.23452
Tmax          0.697005   0.256868   2.713  0.00666 **
Ws            0.536338   0.267109   2.008  0.04465 *
Tmin         -0.893465   0.275905  -3.238  0.00120 **
Rh            0.129563   0.049981   2.592  0.00954 **
Eff.Rn        0.021145   0.008463   2.499  0.01247 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 49.466  on 11  degrees of freedom
Residual deviance: 12.889  on  4  degrees of freedom
AIC: 89.587

Number of Fisher Scoring iterations: 4

> mydata4=glm(Building.Design.Performance~Rn+SI+Tmax+Ws+Tmin+Rh+Eff.Rn, family = poisson())
> summary(mydata4)
```

```
Call:
glm(formula = Building.Design.Performance ~ Rn + SI + Tmax +
    Ws + Tmin + Rh + Eff.Rn, family = poisson())

Deviance Residuals:
       1         2         3         4         5         6         7         8
 0.15334   0.48955   0.13508  -0.02211  -2.68020   2.22270   1.42740  -2.06709
       9        10        11        12
-1.08409   1.23578   0.19159  -0.62535

Coefficients:
             Estimate Std. Error z value Pr(>|z|)
(Intercept)  7.835259   4.673380   1.677   0.0936 .
Rn           0.007732   0.004121   1.876   0.0606 .
SI           0.207943   0.186112   1.117   0.2639
Tmax        -0.131036   0.233687  -0.561   0.5750
Ws           0.571588   0.280350   2.039   0.0415 *
Tmin        -0.226017   0.239649  -0.943   0.3456
Rh           0.004794   0.038718   0.124   0.9015
Eff.Rn      -0.010675   0.009492  -1.125   0.2608
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 44.955  on 11  degrees of freedom
Residual deviance: 21.846  on  4  degrees of freedom
AIC: 98.804
```

Number of Fisher Scoring iterations: 4

						TMAX						
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1950	32.1	33.2	33.3	32.7	30.7	29.4	27.9	27.9	29	29.9	31.4	32.4
1951	32.1	33	33.3	33.5	30.9	29.5	28.5	28.2	29.4	30.3	31.6	32.5
1952	32.3	33.5	33.9	32.6	31	29.6	28.4	27.8	28.7	30.4	31.6	32
1953	33.1	33.3	32.1	33.2	31.8	30.4	29.6	29.2	30.2	31.5	32	32.7
1954	34.3	33.7	33.2	32.3	31.7	30.4	28.3	28.3	29.8	30.3	31.8	32.6
1955	32.6	34.1	32.9	33.1	31.8	30.6	29.1	28.5	29.6	29.8	32.9	32.9
1956	33.4	33.8	32.5	32.4	31.4	29.9	28.7	28.8	29.7	31.1	32.3	31.4
1957	32.6	35	34.1	32.8	31	31.2	29.7	29.3	29.8	30.2	31.4	32
1958	33.1	34.6	35.1	32.9	31.7	29.9	29	29.2	29.8	30.5	31.5	33.1
1959	33.3	35.1	35.6	33.3	31.4	30.3	29.6	29.4	29.3	30.7	32	33.1
1960	32.8	35.1	34.7	32.9	32.1	30.4	29.3	29.2	29	30.7	32.1	32.8
1961	36.6	33.9	35.5	33.3	32.2	30	28.9	29.4	29.4	30.5	33.3	33.3
1962	33.9	34.4	32.7	32.7	31.6	30	29.4	28.9	29.4	30.5	31.6	32.7
1963	33.3	33.9	33.9	32.7	31.6	31.1	30	30	31.1	31.6	32.7	33.9
1964	33.3	36.1	35	32.7	31.6	29.4	29.4	29.4	30.5	31.6	32.7	33.3
1965	32.7	33.3	34.4	33.3	31.6	31.1	29.4	28.9	30.5	31.1	32.7	33.3
1966	33.9	35.5	36.1	33.3	31.6	31.1	30.5	30.2	30	31.1	32.7	33.3
1967	32.7	35.5	35	33.4	31	30.7	28.7	27.3	29.5	31.2	32.5	33.7
1968	32.9	33.4	34.4	33.5	31	29.5	28	28.4	29.6	30	31.7	31.4
1969	32.1	32.8	34.2	32	30.9	29.9	28.6	28.6	29.5	30.7	31.7	31.1
1970	31.1	33.2	33.3	33.7	31.9	29.6	27.7	28.8	29.3	31.4	32.4	33.8
1971	33.1	34.2	34.4	33.2	32.1	30.3	29.1	28.9	29.8	31.1	32.4	33.3
1972	34.2	35.1	34.2	32.1	31.9	31.1	31.2	29.9	31.1	31.4	33.3	33.9

1973	34.1	35.8	35.2	33.8	32.9	31.2	29.8	29.9	30.3	32.4	33.3	33.1
1974	33.3	34.6	34.8	33.2	32.1	31.2	29.2	31.1	30.2	31.4	32.9	33.1
1975	33.1	35.3	35.4	34.1	31.9	31.4	29.1	29.8	29.2	31.2	31.9	33.2
1976	34.1	33.3	33.2	32.9	31.1	30.2	28.4	28.9	29.7	29.8	31.2	33.4
1977	32.1	34.1	35.4	33.9	33.1	29.8	28.7	28.9	29.6	30.8	33.9	33.2
1978	33.9	34.8	33.7	32.2	32.1	30.3	29.1	29.9	30.1	31.3	32.1	33.3
1979	34.9	34.1	34.3	34.9	31.7	29.8	29.9	29.1	31.2	31.3	31.9	31.7
1980	33.9	34.7	33.5	34.2	32.1	31.4	29.9	29.7	29.6	29.8	31.6	31.8
1981	32.2	35.4	34.9	34.6	30.9	30.5	29.1	29.4	30.2	31.3	32.1	34.2
1982	34.2	34.3	33.9	34.2	31.9	29.8	29.6	29.7	28.9	31.2	32.3	33.3
1983	32.2	35.8	36.5	36.7	30.3	30.2	29.4	29.8	31.5	33.7	33.2	32.9
1984	34.4	35.9	34.8	32.7	31.9	31	29.5	29.8	29.9	30.6	31.8	32.2
1985	34.2	35.4	34.2	32.1	32.3	30.3	30.2	29.6	29.9	31.2	33.3	32.4
1986	34.4	35.8	33.2	34.3	32.1	31.4	29.4	29.2	29.9	30.9	32.1	32.3
1987	34.4	34.9	35.2	35.4	33.9	30.8	31.2	29.9	31.2	32.1	34.4	34.2
1988	34.2	36.9	35.2	34.3	32.4	30.8	29.9	29.7	30.3	31.1	33.2	32.4
1989	33.3	35.2	35.9	33.8	31.1	31.4	29.9	29.4	29.8	30.5	33.3	33.2
1990	33.9	35.3	37.5	34.4	32.1	30.7	29	29.3	29.8	30.7	32.2	32.1
1991	33.5	35.3	34.5	32	31.2	31.1	29.3	29.2	30.2	30.3	32.4	32.1
1992	32.5	35.9	34.4	33.2	31.9	29.8	29.3	28.8	30	30.8	31.6	38.3
1993	33.3	35.4	34.3	33.3	32.1	30.7	29.6	29.1	30.3	31.1	32.4	31.9
1994	32.6	35.1	35.7	33.3	31.7	30.9	29.6	28.2	30	30.9	32.7	32.8
1995	33.6	35.5	35	33.9	31.6	30.5	29.5	29.4	30.6	30.8	32.2	33.5
1996	34.4	35	34.4	32.8	31	31.2	29.7	29.3	30.4	30.7	32.4	33.5
1997	33.3	36.1	35	32.7	31.6	29.4	29	29.2	29.8	31.4	33	33.4
1998	33	36.9	36.4	35	33	32	30.3	29.6	30	31	33.9	33.5
1999	33.9	34.6	35	33.6	32	31	30.1	30.1	30	30.3	32.9	33.3
2000	34.3	34.3	36	34	32.6	31.1	30.1	29.3	30.4	31	33.4	33.3
2001	34.2	35.5	34.6	33.3	32	31	29.8	28.8	30	31.4	34.1	34.6
2002	33.8	35.7	35	33.3	32.8	31.1	30.5	29.7	30	30.8	33	34.1
2003	34.6	36.1	36	34.4	33.3	30.4	30.4	30.5	30.4	32.1	33.4	33.5

2004	36	37	34	32	32.9	31.2	30.4	29.9	30.2	32.4	33.3	33.6
2005	33.6	34.8	34.5	32.8	31.9	31.8	30.2	30.1	31.1	31.7	32.3	33.1
2006	33.1	34.4	35.2	33.4	31	30.7	28.7	27.3	29.2	29.5	32.9	31.7
2007	30.9	33.5	33.5	32.2	30.8	28.7	27.8	27.8	28.9	30.1	31.3	32
2008	31.2	33.1	31.7	32.8	30.9	29.8	28.9	27.9	29.2	30.2	31.8	32.4
2009	33.2	34.1	34.8	33.7	31.9	29.6	27.7	28.8	28.7	30.4	32.3	32.2
2010	34.9	36.1	36.6	35.2	32.5	31.2	30	30.1	30.2	31.3	33.1	33.3
2011	34.2	35.5	34.6	33.3	32	31	29.8	28.8	30	31.4	34.1	34.6
2012	33.8	35.7	35	33.3	32.8	31.1	30.5	29.7	30	30.8	33	34.1

Rainfall

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1950	27.7	11.7	58.9	189.7	341.6	264.9	222.5	45.5	228.6	249.7	61	0
1951	15.2	10.9	32.3	95.3	251.7	128	305.1	208.3	168.9	186.7	32.3	0
1952	18.3	39.9	29.5	121.2	285	271	202.7	136.7	402.8	390.4	32.3	36.3
1953	4.1	56.4	167.9	78.2	223	230.6	295.4	38.6	287.5	195.8	37.6	0
1954	0.3	99.3	154.7	240.3	208	239	147.3	214.4	102.6	283.5	81	23.4
1955	60.2	15.2	58.4	109.9	229.1	188.7	358.4	166.9	319	249.4	1.8	0
1956	0	69.1	201.2	188.2	137.2	263.1	152.9	30.7	309.6	304.3	37.8	108.5
1957	0	2.5	97.8	224.8	140.2	37.6	357.1	286.8	397.3	194.6	144.8	1.8
1958	31.8	3	18.8	118.4	292.9	100.6	42.9	172.2	238.8	278.9	13.7	0
1959	2.8	0.8	69.3	193.7	184.3	253.7	172.2	135.9	191	237.5	32.8	0
1960	60.7	0	17.5	315.7	222.8	173.5	220.5	322.6	273.6	217.2	36.1	6.4
1961	60.5	0	16.3	86.6	110	244.6	421.9	13.5	246.9	211.8	0	0
1962	29.5	0	256.8	103.1	230.9	341.6	135.4	122.9	260.9	252.2	93	11.2
1963	27.9	47.5	141.5	203.5	350	228.1	227.1	400.1	206	152.9	9.4	11.4
1964	8.6	0	93.5	207.8	191.8	289.1	255.5	71.4	233.7	150.9	61	0
1965	117.3	23.6	75.4	224.3	136.4	359.9	252	334.5	279.1	101.9	0	5.1
1966	8.9	0	92.5	174.8	259.6	286.5	141.7	104.6	321.3	246.1	40.1	4.8
1967	0	33.3	248.2	121.4	275.6	433.3	146.1	113	377.2	99.8	116.8	0
1968	0	82.3	65	34	483.1	240.3	172.7	141.7	103.4	271.5	31.2	4.3

1969	0	15.5	105.2	116.8	174.2	394.7	234.4	183.4	349.8	179.3	0	0
1970	2	0	35.8	212.3	405.4	609.3	238.8	353.8	514.9	345.2	109.7	0
1971	0	21.3	92.2	136.1	101.7	260.8	350.4	192.5	564.4	138.4	Trace	Trace
1972	17	10.7	113	205.2	316.5	239.8	114.6	147.1	365.5	284	0.3	41.1
1973	0	6.1	64.8	66	160.8	244.6	109	340.9	354.3	210.3	0	10.2
1974	0	21.6	35.6	152.1	218.4	207.3	317.5	336.8	349	341.4	0	0
1975	0	33.5	21.8	151.9	238	221.2	238.5	108.7	225	154.2	56.1	0
1976	6.4	109.5	72.6	134.9	301.8	153.9	227.1	213.6	253.2	301.8	11.2	43.4
1977	22.1	3.1	54.8	29.7	205.6	321.4	158.5	182.9	298.6	267.1	0	2
1978	1.8	2	102.3	236.4	239.5	489.6	87	183.8	364.6	260.4	15.4	0.3
1979	0.5	75.9	64.3	28.7	199	237.1	364.8	305.4	208.4	165.8	46.9	0
1980	0	24.2	56.7	76	314.1	228.7	228.6	316.7	594.6	176.8	74.4	0
1981	4.3	1.6	30.9	85.8	194.6	219.2	270.6	185.7	395.9	315.6	0	0
1982	27	57.3	49.3	115.8	315.5	216.2	265.3	92.3	218.1	209.8	0	0
1983	0	0	4	3.3	186	101.1	251.4	92.2	248.2	24.2	0	2.7
1984	0	0	16.1	137.9	130.6	350.5	305.6	385.8	309.5	122.5	20.9	0
1985	16.6	0	206.1	127.8	291.7	202.8	193.5	462.6	259.4	157.8	12.6	Trace
1986	2.1	9.8	127.1	97.8	238.9	141.9	270.4	198.8	206.3	101.6	55.9	0
1987	0	0	33	148.7	173.6	200.5	245.1	292.3	222.7	135.7	0	0
1988	7.1	0	46.4	95.3	154.9	220.3	219.3	226.4	285.2	206.1	0	0
1989	0	0	4.4	167.9	278.7	182.6	162.2	413.4	217.4	217.1	0	0
1990	0.5	0.5	0	181.5	89.7	279.4	508.3	359.1	317.5	318.8	2.3	25.8
1991	0	37.6	63.4	197.1	346.4	244.8	320.2	264.5	230.5	253.5	2.5	0.7
1992	Trace	0	111.5	200.9	194	354	313	149.3	249.7	105.3	28.8	Trace
1993	0	5.1	62.8	148.9	109.9	263.7	186.7	389.8	243.5	72.9	82.9	11.6
1994	33.8	0	9.7	144.5	211.2	140	216	187.2	331.9	181.6	Trace	0
1995	1.6	Trace	90.2	194.1	263.9	356.7	340.2	432.1	192.4	261.7	35	0
1996	Trace	26.7	48.6	160.9	277.2	289.6	368.3	268.4	176.3	303.4	0	0
1997	Trace	0	111.6	261.3	376.1	344.9	226.8	235	392.3	242.2	68.1	4.1
1998	0	6.1	25.8	161.1	188.7	285.9	259.2	96.2	256.6	217.4	0	0
1999	0	15.7	30	103.6	223.5	316.8	206.4	101.2	195.1	291.6	24.3	0

2000	32.4	0	32.3	202	357.5	206.1	289.5	331.8	339.7	226.5	Trace	0
2001	0	28	72.5	305.5	273.8	188.8	152	130.6	407.9	118.1	Trace	0
2002	0	46.5	10.4	159.1	219.7	296.4	263.3	121.9	270.9	332.5	1.5	0
2003	Trace	0	2.9	74.6	234.3	286.9	400.4	290.2	334.4	227.4	39.8	0
2004	6.4	4.8	186.8	305.5	222.3	284.7	174.1	272.3	258	22.1	33.1	0
2005	Trace	26.9	20.8	115.6	170	258.3	277.6	292	283.6	228.5	24.1	19.1
2006	43.9	4.6	78.9	138.4	375	369.2	402.5	188.3	261.8	233.7	0	0
2007	0	9.4	70	93.9	288.4	306.4	329	261.9	286.1	265.8	Trace	0
2008	1.2	0	56.7	191.6	281.2	250.6	221.3	338.4	300.2	97.2		
2009	Trace	Trace	11.1	112.4		206	281.1	193.6	204.7	393.3	32.1	0
2010	Trace	Trace	2.2	162.8	187.4	403.4	130.3	153.2	439	234.9	1	0
2011	0	47.3	0	0	0	189.8	194.9	0	443.6	153.8	2	0
2012	39	21.2	Trace	129.5	288.7	283.5	388.2	312.5	393.2	210.6	73.9	0

SUNSHINE HOURS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1961	6.3	7.6	6.3	5.8	5.9	4.8	3.1	4.7	3.7	5.8	8.1	8.1
1962	7.6	6.5	6.1	6.8	6.6	4.5	4.1	3.3	3.8	4.9	6.6	7.1
1963	7.4	6.4	5.5	6.1	5.9	6.3	4.1	3.8	4.3	5.8	7.5	7.2
1964	5.4	7.3	6.8	6.7	5.7	3.5	4.2	3.5	4.8	6.4	6.5	7.1
1965	6.3	7.2	6.8	6.2	6.1	6.1	3.1	3	3.9	6.1	7.2	7.3
1966	7.5	7.4	6.6	6.2	5.8	5.1	4.3	3.4	3.3	5.1	7.1	7.7
1967	7.2	7.2	5.9	6.5	5.7	5.7	3.4	3.2	3.9	4	5.1	5.3
1971	4.3	7	7.4	6.7	5.7	4.9	3.7	2.5	3	3.9	5.1	5.1
1972	8	7	6.3	5.3	4.2	3	4.4	7.9	5.7	3.2	5.7	4.8
1973	5.1	5.2	4.6	6	6.1	5.2	4.6	4.3	4.2	5.9	8.4	6.7
1974	3.3	5.2	6.5	6.3	5.6	5.4	3.4	4.2	3.2	5.2	7.8	7.5
1975	4.4	5.5	5	6.8	6.2	5.9	3.7	3.4	3.2	5.2	5.7	8.1
1976	6.9	6.3	6	4.9	5	5.3	2.5	2.7	4.4	4.1	6.8	7.1

1977	5.1	3.4	4.1	5.1	6.5	5.2	4.5	3.7	4	6	8.5	7.8
1978	7.6	6.8	6.7	5.1	6.8	5.6	3.4	3.8	3.8	5.7	7.9	8.1
1979	7.8	6.1	5.2	6.1	6.3	5.4	4.4	2.9	4.7	4.7	6.3	7.2
1980	6.9	5.2	5.5	5.9	5.4	5.6	3.2	3.5	4.4	4.6	6.6	6.6
1981	5.5	6.9	5.7	6.5	5.7	5.7	3.4	3.2	3.9	5.8	6.7	7.9
1982	6.5	5.4	6.2	6.7	5.7	4.9	3.7	2.5	3	5.1	6.5	7.1
1983	4.4	6.8	4.9	6.4	5.8	4	3.6	2.6	4.3	5.2	6.8	7.1
1984	4.9	6	4.8	5.2	6.2	6.3	5.4	4.8	4.4	5.5	6.4	6.2
1985	5.6	4.9	5.2	5.6	6.1	4.8	4	4.6	4.5	6	6.8	5.3
1986	5.8	6.2	5.5	6.5	6.3	5.4	2.7	3.9	4.3	5.9	7.1	5.5
1987	5.7	4.9	5.4	6.1	6.2	5.1	5.3	4.3	4.7	6.1	7.6	7.6
1988	4	6.9	5.2	6.2	6.2	5.3	3.5	2.9	3.8	5.7	8.5	5.1
1989	8	6.9	6.2	6.8	5.8	4.5	3.7	2.8	4	5.5	7.9	7.4
1990	5.6	5.8	7.3	6.2	5.5	5.3	3	3.1	3.8	6	6.1	5.6
1991	5.8	6.3	5.7	5.6	4.8	5.3	3	2.6	3.5	4.8	6.7	6.4
1992	5.2	7	3.2	5.4	4.9	3.9	3.1	2.5	3.3	4.9	7.2	8.2
1993	5.9	6.2	6	5.8	6.1	5.2	3.5	2.6	4.6	5.9	6.4	6.4
1994	5.6	5.1	6.7	6.1	6.2	4.8	2.7	2.6	3.5	5.6	8.3	7.8
1995	6.6	5.9	6.5	6.3	7.1	5.4	5.3	4.8	4.3	5.2	6.8	7.1
1996	7.5	6.6	5.7	6.2	7	5.1	3.5	4.6	4.4	5.5	6.4	6.2
1997	7.2	6.4	5.9	6.1	6.9	5.3	3.7	3.9	4.5	6	6.8	5.3
1998	7.1	6.5	6.4	6.8	6.5	4.5	3	4.3	4.3	5.9	7.1	5.5
1999	7.4	6.3	6.5	7	6.5	5.3	3	2.9	4.3	5.6	7.4	8
2000	5.6	6.7	4.8	5.3	6.3	5.3	4.6	3.6	4.9	5.6	7.2	7.1
2001	4.4	6.8	4.9	6.4	5.8	5.4	2.7	3.9	4.3	5.2	6.8	7.1
2002	4.9	6	4.8	5.2	6.2	5.1	5.3	4.3	4.7	5.5	6.4	6.2
2003	7.2	6.4	5.9	6.1	6.9	5.3	3.7	3.9	4.5	6	6.8	5.3
2004	7.1	6.5	6.4	6.8	6.5	4.5	3	4.3	4.3	5.9	7.1	5.5
2005	7.4	6.3	6.5	7	6.5	5.3	3	2.9	4.3	5.6	7.4	8
2006	8	6.9	6.2	6.8	5.8	4.5	3.7	2.8	4	5.5	7.9	7.4
2007	5.6	5.8	7.3	6.2	5.5	5.3	3	3.1	3.8	6	6.1	5.6

2008	5.8	6.3	5.7	5.6	4.8	5.3	3	2.6	3.5	4.8	6.7	6.4
2009	5.2	7	3.2	5.4	4.9	3.9	3.1	2.5	3.3	4.9	7.2	8.2
2010	5.9	6.2	6	5.8	6.1	5.2	3.5	2.6	4.6	5.9	6.4	6.4
2011	5.6	5.1	6.7	6.1	6.2	4.8	2.7	2.6	3.5	5.6	8.3	7.8
2012	6.6	5.9	6.5	6.3	7.1	5.4	5.3	4.8	4.3	5.2	6.8	7.1

WIND SPEED (mtrs./s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1961	5	3	5	4	3	3	3	5.1	3	3	2	3
1962	3	4	4	3	3	3	3	4	3	2	2	2
1963	2	4	3	4	3	3	3	2	3	3	3	2
1964	3	4	5	4	4	4	5	3	3	3	3	0
1965	2	3	4	3	2	2	3	3	2	3	3	3
1966	3	4	4	3	3	3	3	3	3	3	2	3
1970	5	6	7	3	4	3	3	3.2	3	3	3	4
1971	6	6	7	7	6	3	5	3.1	3	5	3	3
1972	4	5	6	5	5	5	6	6	6	5	5	6
1973	7	7	8	8	8	7	7	7	6	7	6	5
1974	6	7	8	8	7	7	7	7	6	6	6	8
1975	8	8	8	8	7	7	7	8	7	6	5	7
1976	7	7	7	7	6	6	7	6	5	5	5	5
1977	4	5	5	6	5	5	5	6	4	4	3	5
1978	5	5	5	5	5	5	5	6	4	3	4	4
1979	4	4	5	6	4	4	5	4	4	4	4	6
1980	4	4	6	6	5	5	5	5	4	4	4	4
1981	6	5	6	7	5	6	5	5	6	4.8	0	0
1982	5	6	5.8	6	4.7	5	6	7	5	5	5	5
1983	11	7	6	8	7	7	7	7	6	5	5	5
1984	6	6	8	7	5	6	5	6	5	5	4	6

1985	5	5	6	6	7	6	5	5	4	5	4	6
1986	5	6	7	7	6	6	7	7	6	6	5	7
1987	6	6	7	7	8	6	6	6	5	5	5	6
1988	6	6	8	8	6	6	6	7	6	5	4	6
1989	9	8	8	8	6	5	4	5	5	5	4	5
1990	5.4	6.8	6.2	7.5	6.7	6.7	6.1	6.1	6.1	5.5	4.5	4.5
1991	6.1	6.7	6.9	6.1	5.1	5.9	5	5.9	4.7	4.6	3.4	6.1
1992	7.2	5.9	5.1	4.6	4.2	4.5	5.6	7.1	5.2	4.8	5.6	5.8
1993	6.7	5.2	7.1	6.7	5.3	5.2	6.2	5.4	4.6	4.6	4.6	5.9
1994	6.1	3.9	7	5.9	4.9	5.3	5.8	6	5.1	4.2	4.9	7.2
1995	5.8	4.8	6.3	5.6	4.7	5.4	5.4	4.6	4.7	4.5	5.5	4.5
1996	4.7	5.9	6.5	6.2	6.3	5.6	5.8	5.5	5.4	5	5.6	4.1
1997	5.1	7.8	5.6	5.6	4.3	5.2	6.5	5.6	5.4	4.7	3.9	5
1998	7.2	5.9	6.4	6.9	5.8	5.2	6.4	0.7	5.7	4.6	3.8	5.3
1999	5.9	6	8	6.4	5.8	5.2	5.9	6	5.1	4.6	3.7	5.7
2000	5.6	6.8	6.6	7.4	5.7	5.4	6	6.1	5.6	4.5	4.3	6.3
2001	5.9	6.6	6.7	6.5	5.7	5.5	5.8	6.3	5.5	4.4	4	4.8
2002	7.2	6.3	7	6.8	5.7	5.5	5.3	5.7	5.2	4	4	6
2003	6.1	6.7	6.9	6.1	5.1	5.9	5	5.9	4.7	4.6	3.4	6.1
2004	7.2	5.9	5.1	4.6	4.2	4.5	5.6	7.1	5.2	4.8	5.6	5.8
2005	6.7	5.2	7.1	6.7	5.3	5.2	6.2	5.4	4.6	4.6	4.6	5.9
2006	5.4	6.8	6.2	7.5	6.7	6.7	6.1	6.1	6.1	5.5	4.5	4.5
2007	6.1	6.7	6.9	6.1	5.1	5.9	5	5.9	4.7	4.6	3.4	6.1
2008	7.2	5.9	5.1	4.6	4.2	4.5	5.6	7.1	5.2	4.8	5.6	5.8
2009	6.7	5.2	7.1	6.7	5.3	5.2	6.2	5.4	4.6	4.6	4.6	5.9
2010	6.1	3.9	7	5.9	4.9	5.3	5.8	6	5.1	4.2	4.9	7.2
2011	5.8	4.8	6.3	5.6	4.7	5.4	5.4	4.6	4.7	4.5	5.5	4.5
2012	4.7	5.9	6.5	6.2	6.3	5.6	5.8	5.5	5.4	5	5.6	4.1

WIND DIRECTION

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1961	S	S	S	S	S	S	S	S	W	W	S	S
1962	S	N	S	S	S	S	S	W	W	S	S	W
1963	W	W	S	S	S	S	S	W	S	S	S	W
1964	W	SW	S	S	S	S	S	S	SW	S	SW	W
1965	W	W	SW	S	S	W	SW	W	W	W	W	NE
1966	W	NE	W	SW	SW	S	SW	SW	SW	SW	SW	E
1970	NE	NE	W	SW	SW	SW	SW	SW	SW	SW	SW	W
1971	NE	SW	SW	SW	S	SW	W	SW	SW	SW	W	W
1972	NW	NE	W	W	SW	SW	W	W	W	W	S	NW
1973	NW	NW	SW	SW	SW	SW	W	W	W	W	S	NW
1974	NW	N	SW	SW	W	W	W	W	W	S	S	NW
1975	S	S	S	S	S	S	S	S	W	W	S	S
1976	W	W	SW	S	S	W	W	W	W	W	S	NW
1977	NW	NE	W	W	SW	SW	W	W	W	W	S	NW
1978	NW	NW	SW	SW	SW	SW	W	W	W	W	S	NW
1979	NW	N	SW	SW	W	W	W	W	W	S	S	NW
1980	S	S	S	S	S	S	S	S	W	W	S	S
1981	S	N	S	S	S	S	S	W	W	S	S	W
1982	W	W	S	S	S	S	S	W	S	S	S	W
1983	W	SW	S	S	S	S	S	S	SW	S	SW	W
1984	NW	NE	W	W	SW	SW	W	W	W	W	S	NW
1985	NW	NW	SW	SW	SW	SW	W	W	W	W	S	NW
1986	NW	N	SW	SW	W	W	W	W	W	S	S	NW
1987	S	S	S	S	S	S	S	S	W	W	S	S
1988	W	W	SW	S	S	W	W	W	W	W	S	NW
1989	NW	NE	W	W	SW	SW	W	W	W	W	S	NW
1990	NW	NW	SW	SW	SW	SW	W	W	W	W	S	NW
1991	NW	N	SW	SW	W	W	W	W	W	S	S	NW
1992	S	S	S	S	S	S	S	S	W	W	S	S

1993	S	N	S	S	S	S	S	W	W	S	S	W
1994	W	W	S	S	S	S	S	W	S	S	S	W
1995	W	SW	S	S	S	S	S	S	SW	S	SW	W
1996	W	W	SW	S	S	W	SW	W	W	W	W	NE
1997	W	NE	W	SW	SW	S	SW	SW	SW	SW	SW	E
1998	NE	NE	W	SW	SW	SW	SW	SW	SW	SW	SW	W
1999	NE	SW	SW	SW	S	SW	W	SW	SW	SW	W	W
2000	W	W	SW	S	S	W	W	W	W	W	S	NW
2001	NW	NE	W	W	SW	SW	W	W	W	W	S	NW
2002	NW	NW	SW	SW	SW	SW	W	W	W	W	S	NW
2003	W	W	SW	S	S	W	W	W	W	W	S	NW
2004	NW	NE	W	W	SW	SW	W	W	W	W	S	NW
2005	NW	NW	SW	SW	SW	SW	W	W	W	W	S	NW
2006	NW	N	SW	SW	W	W	W	W	W	S	S	NW
2007	S	S	S	S	S	S	S	S	W	W	S	S
2008	W	W	S	S	S	S	S	W	S	S	S	W
2009	W	SW	S	S	S	S	S	S	SW	S	SW	W
2010	W	W	SW	S	S	W	SW	W	W	W	W	NE
2011	W	NE	W	SW	SW	S	SW	SW	SW	SW	SW	E
2012	NE	NE	W	SW	SW	SW	SW	SW	SW	SW	SW	W

RELATIVE HUMIDITY @ 09 HOURS (%)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1961	63	53	64	73	78	81	82	73	80	80	71	57
1962	50	58	76	76	78	81	81	81	80	81	77	77
1964	60	62	70	75	79	81	74	83	81	74	72	75
1965	77	71	70	74	76	79	85	84	81	78	73	60
1966	65	59	69	72	81	82	81	81	81	79	76	63
1970	82	69	53	72	80	82	83	84	80	75	77	65

1971	55	72	71	73	77	82	83	83	83	79	69	47
1972	65	69	73	76	80	79	81	83	84	82	68	61
1973	69	66	63	73	78	83	83	85	86	79	63	76
1975	37	66	69	74	81	81	85	81	83	81	79	52
1976	57	73	76	78	82	80	84	81	78	81	71	65
1978	50	70	71	76	78	82	80	81	85	79	65	69
1979	59	73	76	70	79	82	82	87	81	81	78	49
1981	47	62	69	74	81	82	84	84	84	82	61	69
1982	63	59	68	73	80	82	84	80	84	83	64	69
1983	18	56	57	65	77	81	83	83	82	77	71	66
1984	51	62	67	73	78	80	83	83	82	79	71	53
1985	73	53	71	78	78	81	83	84	83	79	79	49
1987	56	72	67	73	76	80	81	84	83	78	71	63
1988	52	67	72	72	79	79	81	81	84	82	75	60
1989	26	39	67	72	79	82	84	87	83	82	74	56
1990	66	50	53	73	78	81	86	83	84	81	76	75
1991	55	71	73	80	83	83	86	86	84	80	78	50
1992	42	49	73	78	80	82	84	83	85	82	67	59
1993	42	52	67	76	79	81	83	87	85	82	75	88
1994	60	66	68	76	82	84	85	88	86	83	69	36
1995	41	62	72	75	82	84	85	89	84	82	64	68
1996	74	70	74	77	80	82	85	86	82	82	61	70
1997	64	31	68	81	80	82	81	85	85	82	80	62
1998	43	57	59	75	79	83	81	81	85	83	78	59
1999	64	72	73	74	82	82	86	83	84	83	78	58
2000	65	43	62	75	80	83	84	86	84	83	74	52
2001	50	49	73	77	81	80	83	85	85	81	73	67
2002	36	59	74	77	79	84	85	84	81	84	76	48
2003	61	69	68	73	76	84	82	82	84	80	75	54
2004	51	55	60	74	80	81	81	84	85	81	76	70
2005	42	67	72	71	79	84	87	81	84	81	77	70

2006	75	76	70	75	83	83	84	82	88	85	65	48
2007	65	43	62	75	80	83	84	86	84	83	74	52
2008	50	49	73	77	81	80	83	85	85	81	73	67
2009	36	59	74	77	79	84	85	84	81	84	76	48
2010	61	69	68	73	76	84	82	82	84	80	75	54
2011	51	55	60	74	80	81	81	84	85	81	76	70
2012	42	67	72	71	79	84	87	81	84	81	77	70

TMIN

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1950	22.7	22.3	23.5	23.2	22.1	21.4	21.4	21.3	21.6	21.3	22.1	22.1
1951	21.9	23	23.5	23.6	22.3	22	21.6	22.1	22.2	22.1	22.5	20.7
1952	23.3	23.9	24.1	23.7	22.9	21.9	21.7	21.9	21.6	21.5	22.6	22.4
1953	23.6	23.3	23.3	23.7	22.8	22.3	22.4	22.4	22.1	21.6	20.2	16.1
1954	19.9	23.1	23.4	22.6	22.6	21.9	21.8	21.7	21.6	21.3	21.7	19.5
1955	18.5	22.6	22.8	23.3	22.4	21.8	22	21.8	22	21.4	21.1	18.4
1956	18.9	22.6	23.1	22.8	22.3	21.4	21.8	21.7	21.7	21.8	22	18.2
1957	19.9	19.2	22.8	23.3	23.3	22.6	22.5	22.3	22.1	21.6	22.1	19.8
1958	20.9	19.4	24.5	23.4	22.4	22.4	21.7	21.9	22.1	21.8	22.4	21.2
1959	20.6	21.7	24.4	23.7	22.9	22.2	22.4	22.1	22	21.7	21.7	18.6
1960	18.3	21.2	22.6	22.9	22.7	22.1	21.9	22.2	21.4	21.9	20.1	21.6
1961	20	18.9	23.3	23.3	23.3	22.2	22.2	21.6	21.6	21.6	20.5	16.7
1962	16.7	22.2	23.3	23.3	22.8	22.2	22.2	22.2	22.2	21.6	22.2	21.1
1963	20	23.3	22.8	23.9	22.8	22.2	22.2	22.2	22.2	22.2	20.5	21.1
1964	20	22.2	23.9	22.8	22.8	22.2	21.6	22.2	21.6	21.6	20.5	22.2
1965	21.6	21.6	23.3	23.3	22.8	22.2	22.2	22.2	22.2	22.2	21.1	19.4
1966	20	21.1	23.9	23.9	22.8	22.8	22.8	22.8	22.2	21.6	22.2	18.3
1967	17.8	22.2	23.3	23.6	23.1	22.1	22	21.8	21.8	21.6	20.2	16.1
1968	19.2	23.1	23.8	24	23.6	22.8	22.8	21.8	22	21.4	21.1	18.4
1969	22.8	23.1	24.2	23.5	22.9	21.6	21.6	21.6	21.2	21.4	22.6	20.7

1970	23.1	24.1	24.6	24.3	23.6	23.1	22.7	22.9	22.3	22	21	18
1971	20.3	23.1	23.6	23.7	22.9	21.8	23.1	22.1	22.1	22.1	21	18.8
1972	20	22.8	23.7	22.7	22.6	22.3	22.7	22.4	22.1	21.9	19.7	19.9
1973	22.4	24.3	24.4	23.6	23.3	22.5	22.7	22.5	22.2	22.6	20.3	21.8
1974	20.1	22.8	24.2	23.2	22.6	22.3	21.9	22.3	21.9	21.8	21	18.1
1975	18.3	23.4	24.3	23.8	22.7	22.1	21.9	22.2	21.8	21.8	22.3	18.3
1976	20.1	23.2	22.9	22.9	21.8	22.2	22.3	21.9	21.8	22.5	22.1	21.1
1977	22.1	22.9	23.8	24.6	23.7	22.6	22.8	22.7	22.6	22.1	21.3	19.9
1978	20.3	24.6	23.9	22.6	22.8	22.1	21.8	22.6	21.8	21.7	20.2	20.3
1979	20.3	23.8	23.7	24.5	22.6	22.7	22.5	22.6	22.1	23.1	23.2	18.4
1980	21.1	23.9	23.7	23.8	22.9	22.7	22.2	22.1	21.9	21.8	21.7	20.3
1981	19.4	22.1	23.9	23.1	22.2	22.9	21.8	21.9	22.2	21.9	20.3	20.3
1982	22.2	22.9	23.7	23.6	23.1	23.2	22.2	22.9	21.8	21.9	21.7	20.3
1983	19.2	23.1	23.8	25.5	23.6	22.8	21.9	21.7	22.6	22.8	23.1	22.1
1984	20.1	23.9	24.8	23.7	22.9	21.9	21.7	21.8	21.1	22.3	22.1	20.2
1985	23.1	21.3	23.9	23.5	22.7	22.9	21.7	21.6	21.5	22.2	23.1	20.3
1986	22.2	23.9	23.7	23.8	22.6	22.8	21.8	21.8	21.9	22.6	22.1	19.3
1987	21.3	23.4	23.6	24.6	23.7	22.6	22.9	22.7	22.5	22.6	23.1	20.2
1988	22.3	24.9	24.7	24.6	22.5	22.7	21.9	22.7	21.6	21.9	22.1	21.2
1989	17.2	21.3	24.6	23.5	22.6	22.7	21.9	21.5	21.6	21.7	22.2	19.3
1990	22.7	22.2	24.2	24.2	23.7	22.5	22.5	22.8	22.6	22.7	23.6	23.1
1991	21.4	25	25.2	23.9	23.9	23.6	22.9	22.6	22.1	21.9	22.3	19.3
1992	19.8	21	24.8	24.5	23.3	22.5	22.4	22.5	22.4	22.5	21.1	19.3
1993	20.4	21.5	23.9	24	23.6	22.8	22.8	22.5	22.5	22.5	22.8	20
1994	21.4	23	25.1	23.7	23	22.7	22.7	21.9	22.7	22.4	21.1	17.8
1995	19.8	22.1	24.9	24.3	22.7	22.6	22.8	22.6	22.7	22.1	20.3	20.4
1996	21.7	24.6	24.5	23.8	23.4	23.1	22	22.5	22.9	22.3	19.7	20.4
1997	22.4	20	23.1	23	22.8	22.8	23	22.9	22.8	21.9	21.7	20.3
1998	21	24.5	24.9	26	25	23	23.1	23.2	23	23	23.5	20.9
1999	22.2	24.9	21.6	24.3	23	23	22.5	22.7	22.3	22.4	23	19.1
2000	22.6	21.4	23.4	24	23.8	22.5	22.8	21.9	22.9	22.7	23.4	19.8

2001	19.4	21.8	24.6	23.9	23	23	21.9	21.7	22.6	22.3	22.1	20.2
2002	23.1	24.1	24.6	24.3	23.6	23.1	22.7	22.9	22.3	22.8	20.5	22.6
2003	23.8	24.3	24.6	23.5	22.6	22.5	21.8	21.8	21.7	21.9	22.2	21.1
2004	20	23.3	22.8	23.9	22.8	22	21.8	21.6	21.6	21.4	22.2	22.7
2005	21.6	22.6	23.3	23.4	22.8	21.9	22.2	21.9	21.4	21.7	22.7	23.2
2006	23.2	22.2	24.4	23.9	23.1	22.3	21.8	21.9	21.6	21.9	23.3	21.6
2007	22.9	23.6	24.1	24	22.2	21.8	21.8	21.2	21.4	21.7	22.5	22
2008	21.6	23.7	23.9	23.6	23.1	22.1	22	21.8	21.8	21.6	22.2	21.9
2009	21.6	22.8	23.4	23.1	22.8	22.1	22.1	21.9	21.6	22.2	22.1	21.3
2010	23.5	25.6	26.5	25.5	24.5	24.1	23.3	23.6	23.1	23.2	24.2	20.2
2011	22.6	21.4	23.4	24	23.8	22.5	22.8	21.9	22.9	22.7	23.4	19.8
2012	19.4	21.8	24.6	23.9	23	23	21.9	21.7	22.6	22.3	22.1	20.2