CHAPTER ONE: INTRODUCTION

1.0 BACKGROUND TO THE STUDY

Globally, the increased rate of energy use has raised concerns over problem of energy supply and exhaustion of energy resources. This has resulted in severe environmental problems such as high energy demand, global warming, ozone layer depletion, air pollution and acid rain. (HkU 2010; Janda & Busch, 1994). The International Energy Agency (IEA) data on energy consumption in the past decades has been upsetting, given that energy use by emerging economies has projected to grow at an annual rate of 3.2%. If this annual rate should continue it will exceed the energy use of developed countries of the world by 2020 (Lombard *et.al*, (2008).

In most developing countries, particularly in Nigeria, energy consumption has been growing rapidly due to recent economic growth and development in infrastructures. The number of new buildings is increasing rapidly in developing countries. This increase in new buildings is accompanied with high energy prices and a market which most often do not encourage the use of efficient technology, Hui,(2000).Available data from Lagos state Ministry of Physical Planning and Development attest to this finding, as seen in the statistics of 30,000 new residential buildings approval for construction permit between 2001 and 2010 of, while about twelve thousand buildings gained approval for construction between 2012 and 2013 (Lagos Bureau of Statistics 2010).This shows a growth rate of 40% in two years over and above that of ten year figures. The energy consumption of this increment, if all the buildings were to be constructed, will be huge when related to IEA annual energy consumption rate prediction, according to Lombard *et al* (2007). The household consumer in the Organisation of European Development Communities (OECD, 2009) noted that worldwide, residential buildings consume about one third of all energy end use. This submission also predicts that energy demand will grow in a reference scenario to a level above 40% higher than the situation in

2007 by 2030. This increase will arise mainly from non-OECD countries, mostly in Asia and Africa in which Nigeria is significant with her population projection of about 200million. This study also projects a growth in Co_2 emissions produced by energy consumption from 28.8 Gegatone in 2007 to 40.2 Gt. in 2030. According to this projection, together with greenhouse gas emission, this will lead to an increase of up to 6^0C in global average temperature. This empirical study of energy consumption in Lagos metropolitan housing environment will ease the situation in developing economy of a prominent city in Nigeria. It is therefore essential to evaluate the energy consumption and pattern of use among various residential buildings in Lagos for many reasons such as global climate change, carbon emission, global temperature increases, comfortable living and other sustainable issues.

At the global scale, the contributions of energy consumption of residential and commercial buildings are between 20% and 40% in developed countries (Hassan, 2008 and Lombard *et. al*, 2007). Unfortunately cities in Africa in general and Nigeria in particular have no documented data to back up this claim because of her non-OECD membership status (Hassan, 2008, Lombard *et al*, 2007; TSO, Geoffrey and Yao kelvin, 2003; EC, 2007).This is highly required for analytical purposes towards the development of energy standard and government policy guidelines. On the strength of this, energy consumption especially in cities with rapid increase in population growth rate like Lagos constitutes the case study of this research.

However, the issues of population growth, nature of urban and rural migration in emerging mega cities, increased comfort level demands of occupants, together with the rise in time spent in buildings have been identified to have raised the trend in energy demand.

This, according to research, will continue in the nearest future until 2030 and beyond. Therefore, energy efficiency in buildings is today a prime objective for energy policy development at regional, national and international levels (Sandar, 2009; Lombard *et al*. 2008).

To reach this point, all relevant stakeholders in the building sector should therefore realise, understand and employ the concept of energy efficiency in building design and construction. This is vital to energy usage which has a considerable impact on the effect of energy consumption of buildings in Nigeria, particularly in Lagos.

Most studies have revealed that up to 50% of the total energy is used in the control of indoor climate for cooling, heating and ventilation (Satamoura and Wouter, 1994). However, in most buildings in tropical regions, the air conditioning system is identified as essential in maintaining cool thermal environment for occupants. Yet, it is often the largest consumer of energy in which 30-60% of building energy is used for cooling and dehumification purposes. Likewise, artificial lighting is ranked second in energy consumption after air conditioning system and yields 15-20% of the total energy consumption. (Baker *et.al*, 2007; Levine *et al*, (2007) and Lam *et al,(*2003) on the fourth assessment report of the International Policy on Climate Change (IPCC) concluded that there is a global potential to reduce approximately 29% of the projected baseline emission from residential and commercial buildings by 2020 and 31% from the projected baseline by 2030 at net negative cost. This report comparing the possible savings potential with other economic sectors such as transportation, industries and agriculture noted that the building sector has the greatest potential in all ramifications. Lagos Bureau of Statistics household survey (2010) result revealed that 61.8%of household dependence on generator for electricity supply in order to cope with shortage of supply might be significant to emission rate from residential buildings in Lagos.

The relationship of these findings and the likely energy consumption implication in relation to about 15million housing deficit of Lagos, with her megacity status could be devastating to comfortable living condition. At the same time, if Hinostroz *et al*, (2007) and Levine *et al* (2007) study on life cycle of buildings and the projected new demand for public and private energy consumption is valid, the housing sector is expected to continue to grow dramatically for the next thirty years. Hence, Hinostroz *et al* (2007) study concluded that in most developing countries, it is necessary to focus on new buildings rather than retrofitting existing buildings.

Thus, the study of energy consumption in residential buildings towards evolving design parameters for energy efficiency in the Lagos environment and those of other major cities in Nigeria may well be the focal point for reducing the nation's overall energy consumption.

1.1 STATEMENT OF THE RESEARCH PROBLEM

The population of Lagos Nigeria continues to increase in accordance with the projections made by the United Nations that the city will become the most populous in the world by 2050. With residential area occupying about 60% of land use in Lagos, the implication of this for housing stocks is immense on energy consumption. Hence, the density pattern with socio-economic and climatic requirements for sustainable living condition becomes a major challenge for the provision of adequate energy for future housing development.

The traditional housing design goals of providing basic shelter and reliable security for occupants of residential buildings in Lagos in particular and Nigeria in general are yet to be attained. However, the essential comfort required by most occupants continues to remain a major challenge in most buildings, without the much reliance on adequate active energy supply. Moreover, the thermal insensitivity nature of most residential building designs, as identified by research, which impacted much on indoor living conditions, is likely to make issue relating to energy consumption worse. This may have propelled the reliance on fossil fuel energy supply by most occupants that may result in emission, despite ICPC global potential to reducing approximately 29% and 31% baseline projected emission from residential and commercial buildings by 2020 and 2030 respectively.

Adebamowo, (2007) identifies poor design of buildings, with regard to poor orientation, inappropriate use of building materials and components in some as the cause of thermal problems of the residential buildings in Lagos. This, most times may result in high energy consumption that can impede comfortable living. The prevalence of this thermally insensitive nature of residential buildings in Lagos may be as a result of failure to employ the right tropical bioclimatic passive design principles, thereby necessitating high energy consumptions for their operations. At the same time, the typical problems – high population density, overcrowding, high traffic congestion and urban heat island – associated with a place with a megacity status are also issues to contend with in Lagos. These are usually responsible for the air and noise pollution of the city environment that necessitate high intensity of energy consumption in Lagos households.

The paradigm shift in the living condition of most residential occupants due to their upward comfort requirement and increased economic level of income, make indoor comfort a significant problem of high energy consumption. The resulting effect of this paradigm may be seen in the new culture of residential buildings and architectural trends of inadequate solar control with attendant high energy consumption consequences. This concern, alongside occupants' reluctance to window opening in preference to sealed up building envelope often results in the use of air conditioners for indoor cooling, as dictated by prevalent building mode. This may be linked with the high level of air and noise pollution in Lagos, which is likely to have enormous impacts on the amount of energy consumed. The consequences of the problem of energy consumption deserve a full-length research and appropriate methods for evaluating its likely design perspective.

The gap in Literature therefore, is in the non-existence of adequately analysed quantitative and qualitative energy consumption data to establish the standard of households' limit of energy consumption. This remains one of the major problems hindering the formulation of energy consumption standard policies and residential building design codes that will specify minimum parameters for energy efficient building designs for the built environment professionals. This, if considered, will solve designers and built up environment professionals' problem toward the design and construction of energy responsive residential buildings in Lagos in particular and Nigeria in general. Hence, this study considers this impact on most thermally insensitive building design for households on energy consumption in the Lagos Metropolis. By this, what is responsible for occupant's reliance on indoor air conditioners in cities in tropical region is investigated.

1.2 AIM AND OBJECTIVES

The aim of this research is to investigate energy consumption in selected residential buildings located in Lagos Metropolis with a view to determining their energy efficiency for improved housing design.

The objectives of this study are to:

(1) examine the characteristics of selected residential buildings, with respect to their energy Consumption in Lagos metropolis;

(2) identify energy consumption indicators of residential buildings in Lagos Metropolis;

(3) investigate the impact of environmental factors on energy consumption in residential buildings in Lagos metropolis;

(4) examine the relationship between occupants' thermal behavioural actions and energy consumption in the area under consideration and

(5) develop a model for projecting energy consumption of residential buildings with different design parameters in Lagos Metropolis.

1.3 RESEARCH QUESTIONS:

(1) What effect do residential buildings characteristics have on energy consumption in Lagos metropolis?

(2) What are the relevant indicators that determine energy consumption of residential buildings in Lagos metropolis?

(3) What are the impacts of environmental variables on occupant's behavioural actions towards energy consumption in Lagos metropolis?

(4) What are the relationships between residential building occupant's behavioural actions and energy consumption in Lagos metropolis?

(5) What model is suitable for projecting residential energy consumption in Lagos Metropolis?

1.4 HYPOTHESES OF THE STUDY

The following hypotheses have been developed to guide the study and aid data collection:

HYPOTHESIS I

There is no significant relationship between residential building characteristics and energy consumption in Lagos metropolis.

HYPOTHESIS II

There is no significant relationship between environmental factors and energy consumption in residential buildings in Lagos metropolis.

HYPOTHESIS III

There is no relationship between weekly energy consumption and actions taken to ensure indoor comfort in residential buildings in Lagos metropolis.

HYPOTHESIS IV

There is no significant relationship between occupant's behavioural actions and energy consumption in residential buildings in Lagos metropolis.

1.5 SIGNIFICANCE OF THE STUDY

The importance of energy as an essential ingredient in economic growth of all nations is well known. Also known is that energy is an important strategy for improving the quality of life. However, the energy crisis of the late 70's and the reality of the current climate change, coupled with greenhouse gas emission and inadequate energy generation in Nigeria have proved intractable. The relationship which links energy consumption with economic development and population growth may also have a devastating effect on Nigeria, especially Lagos with a population estimate of 20 million people as at 2015.

Hence, aligning with the overall motive in developed countries to increase energy efficiency based on environmental thinking becomes imperative in order to overcome the problem associated with energy consumption in Nigeria. However, individuals may find it difficult to understand and appreciate how a reduction in the personal energy consumption will directly influence the environment.

Energy consumption study, analysis and method are potent tools which can be deployed in estimating energy utilisation and capabilities of countries to tackling energy problems. This knowledge is useful in determining how effectively and efficiently a country uses her natural resources. It is also relevant for the identification and application of energy conservation opportunities, as well as dictating the energy strategies and directions of a country or society towards solving this problem. This study therefore serves as a platform for data collection and analysis of energy consumption in order to formulate a standard for the development of a building energy consumption code and policy in a country like Nigeria.

This is in realisation of the 4th Assessment Report of the International Policy on Climate Change (IPCC), with a global potential to reduce approximately 29% of the projected base line emission from residential and commercial buildings by 2020. (Baker *et al*, 2007; and Levine *et al* 2007). For this, other sustainability issues for professionals in the built environment (Architects, Engineers, Planners, Estate Surveyors and academia), revealed that this is of immense benefit.

In the same vain, it will serve as a benchmark and reference for pre-design, while creating a basis for post-design assessment of residential buildings. The building client will be better educated and guided on building energy performances and understandings of the limitations of designers on their expectation at design and construction stages. It will also guide potential building owners on properties investment decisions, with respect to benefits of life cycle cost of building investment returns. In the same medium, the public sector will be better informed on effective energy consumption indicators and energy generation for meeting the sectorial needs of residential buildings in the built environment. Moreover, as a sector that is responsible for 30% -40% of global energy consumption (IPCC, IEA, and OCOED) and improving for energy supply and generation, it will provide the basis for an effective evaluation and determination of the total and actual energy requirement for sectorial generation. As a consequence, the gap between energy demand and supply will be reduced. In the long run too, the study aids energy suppliers in determining adequate and realistic projections in Lagos, while mitigating the problem of epileptic supplies and loss of earnable resources. Further, as noted by environmentalists, health practitioners, as well as national and international agencies, an efficient energy management and consumption may advance Nigeria’s response to various treaties on emission and as a result, preserve Nigeria’s environment for sustainable future generations.

1.6 SCOPE AND DELIMITATION OF THE STUDY

The study focused on the energy consumption of different types of residential buildings in the sixteen metropolitan local Government areas of Lagos. The choice of Lagos was based on its megacity status, together with her population and climatic regional location of warm humid nature which are significant to energy consumption. The residential building types studied include: detached, semi-detached, terrace houses, Block of Flats, Bungalow and rooming houses. The study considered three types of ventilation - natural, mechanical and mixed mode. The geographical location spread consists of mainland, island and water front areas of Lagos. It also covers the three residential areas of high, medium and low densities in both public and private residential areas.

The emphasis on urban areas here is not meant to imply however that those rural areas do not have energy insensitive houses. It instead recognises the prevalence of the urban housing stock with most national housing inventories of poor thermally sensitive designs.

It is difficult to obtain more specific information on households' energy consumption because of the capability of energy supplier's meters to capture all alternative sources of energy supply. This is further complicated by non-affordability of data analysts for the study that can accept and store environmental data over a substantial period.

The study also is limited by the problems of inaccurate data. This is due to the fact that energy supply is not always available for consumption for everyday use by households.

However, this study is limited to longitudinal survey carried out for one year, during the two major yearly climatic (dry and wet) seasons in Nigeria. Fundamentally, energy monitoring is limited to houses connected to the power line grids.

1.7 STUDY AREA

Lagos is considered as the central area of this study because of its large population, economic potentials and social significance in Nigeria. As a city, Lagos is reputed to be the commercial nerve-centre or economic capital of Nigeria with a population arguably put at 9,103,534, according to the National Population Census conducted in 2006. It lies on the Atlantic coast in the Gulf of Guinea in West Africa. The city is located on latitude 06º27′N and longitude03º24′E, with an average population density of 2,695 habitant per square kilometre, (see Fig. 1.1). February to March are the hottest months, with a mean temperature of 30ºc.

Lagos has a warm humid climate with a dust-laden atmosphere. Months of November to March are the main dry season, usually characterized by Hamartan wind with dusty haze from the Sahara desert. The Months of April to October are period of the rainy season each year. During this time, the humidity is over 80% in the morning, but drops below 65% in the afternoon. This remains the major cause of discomfort to inhabitants of Lagos who require high amount of energy to ease the heat produced.

Minimum temperature usually occurs between evening and early morning, while during the afternoon, maximum temperature and high energy demand may be required to ease condition. This is in addition to the residential land use occupying the highest percentage in urban settlements, of about 60% (Oduwaye 2002, Ajayi 1979 and Mabogunje, 1978). Lagos as an emerging mega city cannot be an exception to the issue of energy problem, as experienced in developed countries of the world, with respect to energy consumption for occupants'.

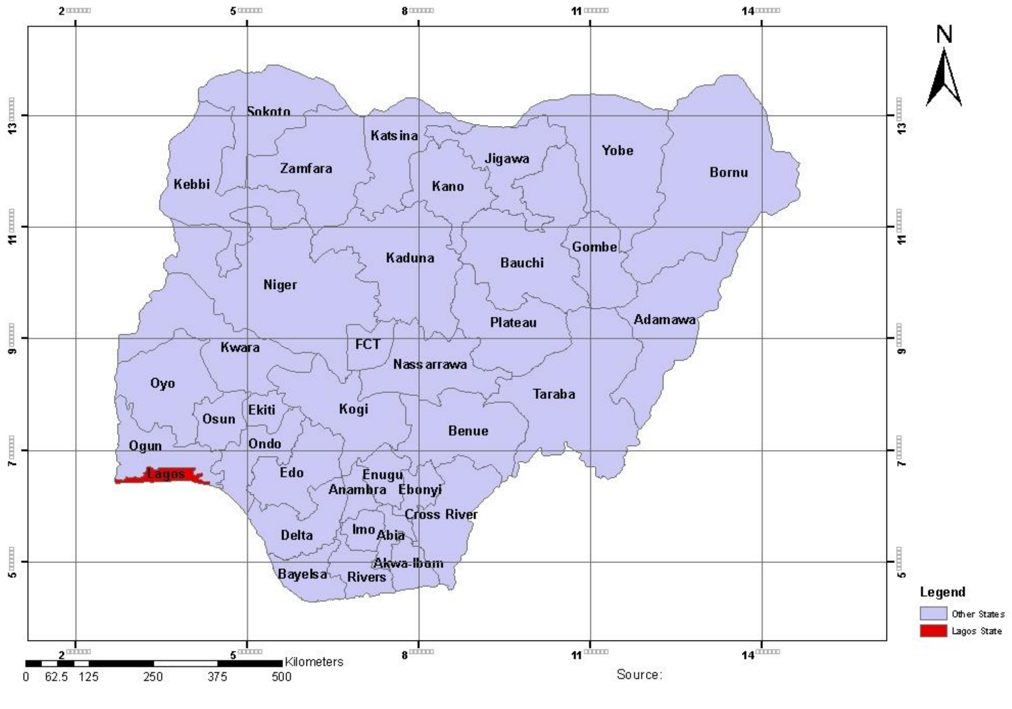


FIG.1.1 Nigeria Map showing Lagos state location

Source: Department of Surveying and Geoinformatics, University of Lagos

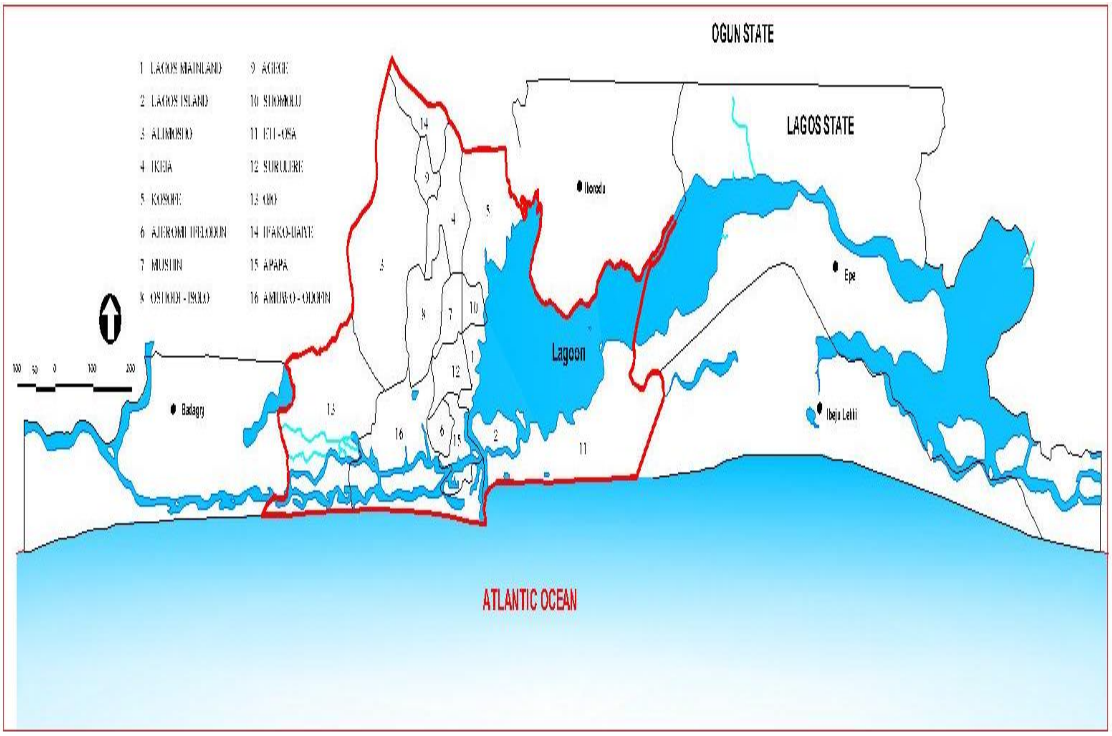


FIG.1.2 Lagos Metropolitant Area Location

Source: Lagos State Metropolitant Projects

1.7.1 CLASSIFICATION OF RESIDENTIAL NEIGHBOURHOOD

Lagos state can be classified into three different residential neighbourhoods, with each consisting of different residential densities. Oduwaye's (2002) study on residential land use and land values in Lagos showed that Lagos Metropolis has 224 residential wards (Independence National Electoral Commission, 1988). The study therefore identified lists of wards that are characterised by identifiable and peculiar residential neighbourhood qualities and dominant residential density type. Hence, the reason for the classification of residential density types identified in the study area as high, medium and low density residential neighbourhoods is shown in Table 1.1 and Fig. 1.3 respectively.

TABLE 1.1: ANALYSIS OF TYPES OF RESIDENTIAL NEIGHBOURHOOD IN THE STUDY AREA

Type of Residential Neighborhood	Number	% of Total
High Density	184	82.14
Medium Density	20	8.93
Low Density	20	8.93
Total	**224**	**100.00**

Source: Independent National Electoral Commission (1998)

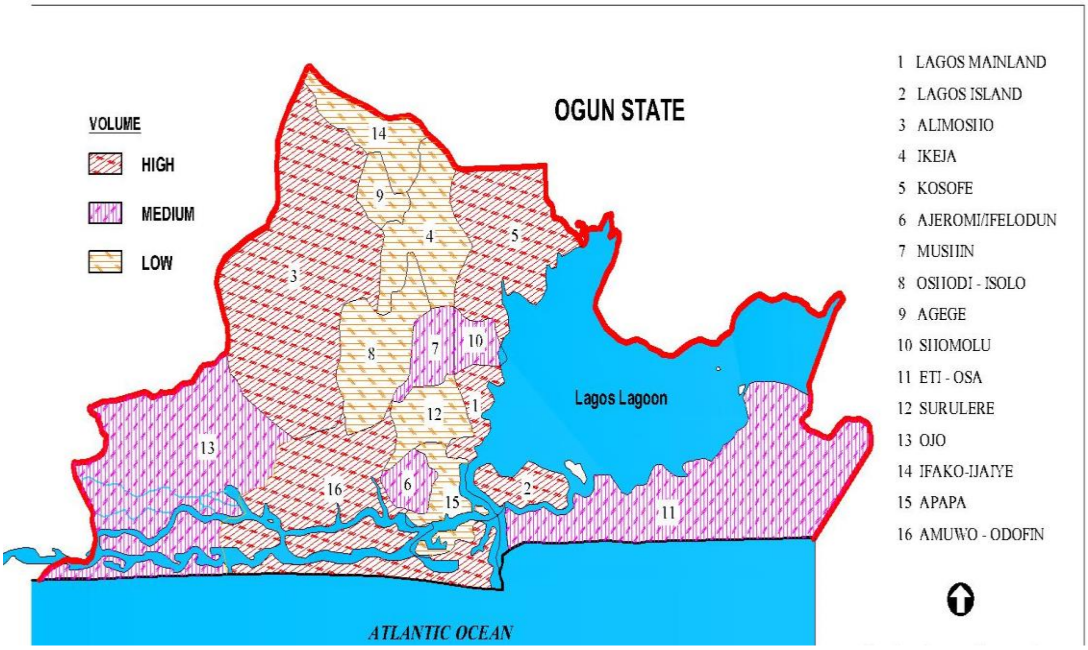


FIG.1.3 Density Classification of Metropolitant Lagos

Source: Lagos State Metropolitant Projects

However, Adebamowo's, (2007) study on Lagos, following the Federal Government of Nigeria local government structure of 20 local government areas by the Lagos State Ministry of Rural Development also show another means of classification. The study identified and classified the study area into 1,151 rural communities, 243 semi–urban communities and 349 urban areas. An updated findings on both submissions show that residential neighbourhood areas and types remained the same, while communities have significantly increased due to improved infrastructural provisions. The study area, then, consists of 931 rural communities, 485 semi urban communities, and 665 urban communities, as indicated in Table 2.9. This could have a significant effect on energy consumption of residential houses.

For the purpose of this study, residential neighbourhood areas and types were used to determine the study population with reference to the Federal Bureau of Statistic (2012) households' survey, considering the fact that energy consumption is driven by occupancy rate of households and building density. The study does not however underplay the minor density changes caused by infrastructural provisions wherein aid new developments.

CHAPTER TWO: LITERATURE REVIEW

2.1 RESIDENTIAL BUILDING CHARACTERISTICS AND ENERGY CONSUMPTION

The building characteristics play a significant role on energy consumption since energy and building relationship are dynamic in nature. This can be clearly explained with the principle of thermodynamic, in which the built environment is formed by the building and other objects constructed in the natural environment. This assertion can be explained further through an extensive literature review drawn from textbooks, scholarly journal articles, and researches undertaken to establish the basic principles for designing energy efficient buildings. The understandings of these principles constitute the essence of energy consumption.

The residential building types and their characteristics vary in accordance with their regional climatic condition and cultural setting. But for purposes of energy consumption studies, residential building types are basically determined by two major characteristics:

I. Building characteristics in term of occupancy affects energy consumption with respect to the number of occupants at a given period of the day (Weekdays and Weekends)
II. The Building ventilation mode, on the other hand, play a major role in determining the energy consumption rate of households. However, for the purpose of this study and the climatic setting, known to be warm and humid, have the following major modes.
    a) Natural ventilation Mode b) Mixed mode ventilation c) Mechanical ventilation mode

Nicol *et al,* (2010) study of occupants control of temperature in mixed –mode buildings seems to provide a design solution in the inevitability scenario of air-conditioning and end energy use control in the study area. A building that is heated in winter, free-running in mid-season and has cooling available in summer, as required, is called a ‘MIXED-MODE’ building. They are usually characterised as likely to consume less energy than a fully air conditioned building. Their energy consumption as well depends greatly on how occupants use the available control, such as windows, fans, heating and cooling technology. The aim of mixed mode building is to maximise energy consumption by good design and judicious control, throughout the proportion of the year that free- running mode is applicable. Mixed mode operation can save energy compared to conventional air-conditioned buildings, as it may also improve air quality, if well designed.

2.1.1 TYPES OF RESIDENTIAL BUILDINGS

Residential building types are generally determined by the cultural setting of the people and their geographical locations. Lagos is not different in this case. The influence of colonial masters namely the English and Portuguese, play a great role in this respect on Lagos early settlement residential house types. The study area is therefore dominated by:

1) SINGLE FAMILY DETACHED DWELLING

This building type is usually occupied by the few elite dated back to history of Lagos. They occupy larger plot of lands, built in the context of the colonial residents in Lagos metropolis. This with expand of greens as found in government reservation areas and in some few private estates recently developed in Lagos metropolis. There occupancy rates are usually maximum of seven numbers and a minimum of five occupants.

Single residential family detached dwelling in Lagos metropolis usually consist of about two number Living rooms, Kitchen and minimum of four to six bedrooms on two levels floor area. In recent time for reasons of scarcity of land and population growth, the colonial large expanse occupation has given way for more compact forms, yet with about the same number of spaces for occupants, as shown in PLATE 2.1, FIGS. (2.1a,b and c).

PLATE 2.1 Detached Duplex at Ikeja

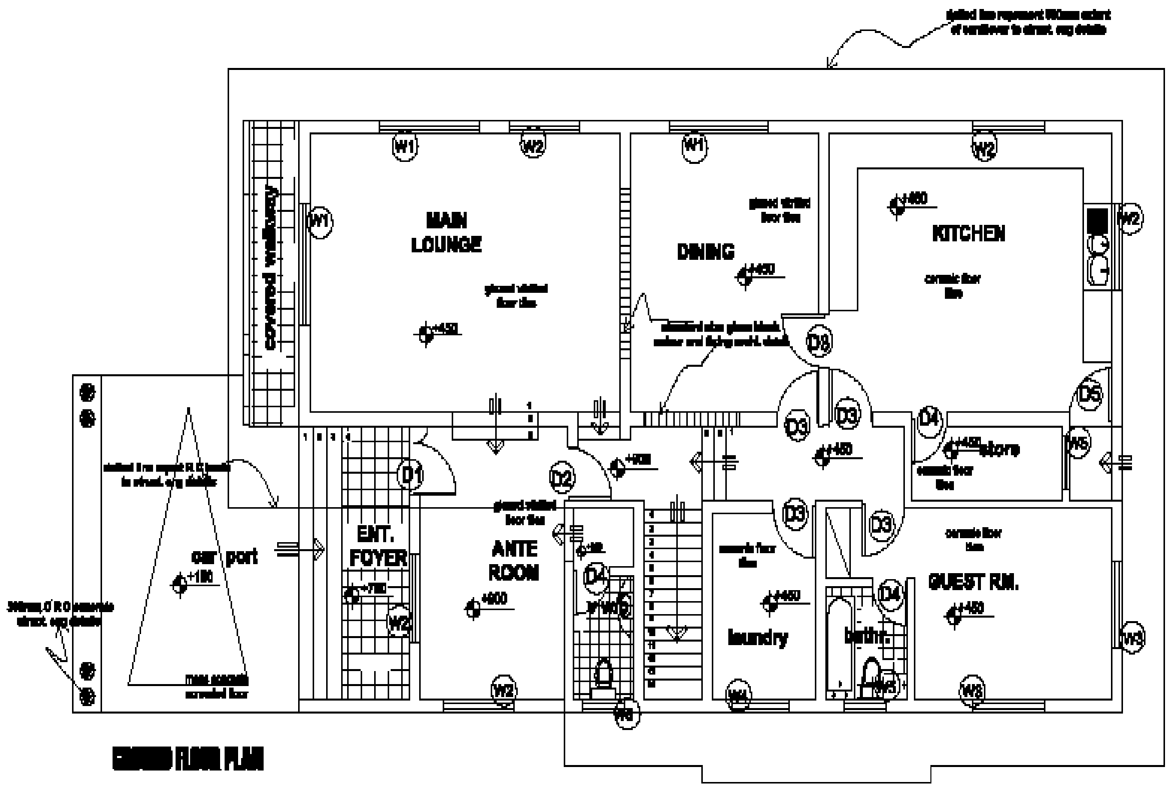


FIG.2.1a Ground Floor Plan of a Typical Detached Duplex Building

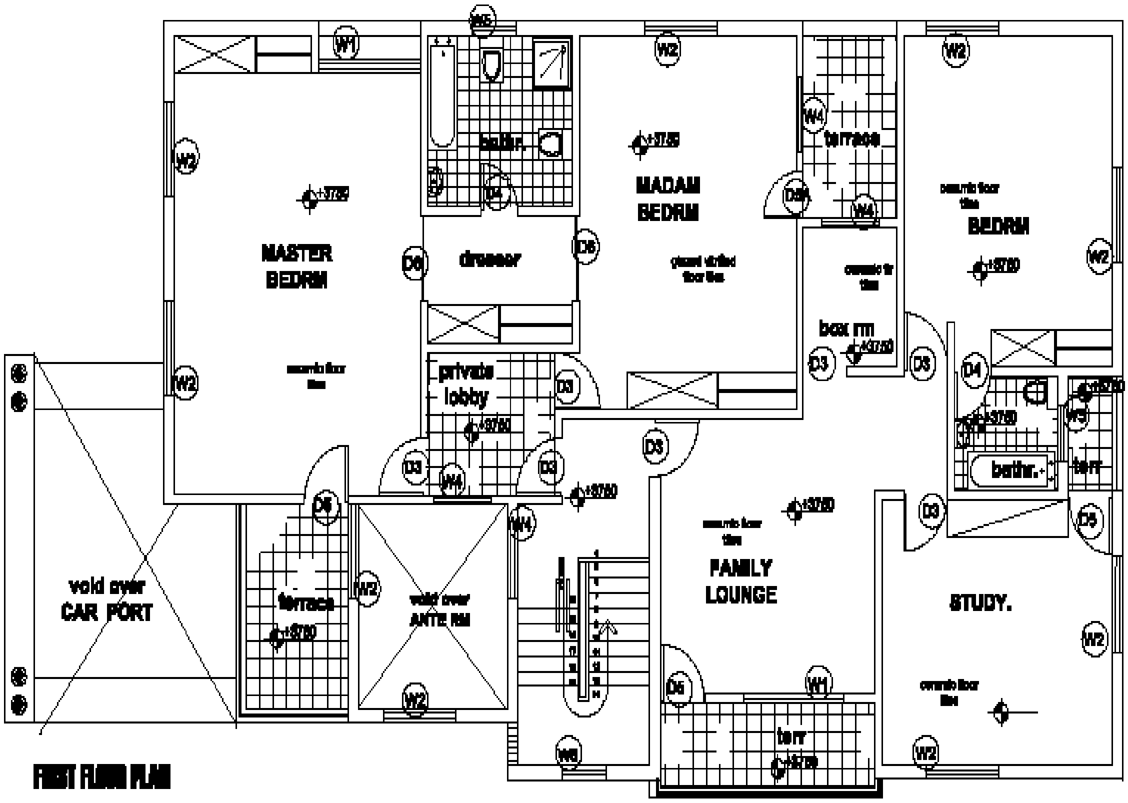


FIG.2.1b First Floor Plan of a Typical Detached Duplex Building

FIG.2.1c Approach Elevation of a Typical Detached Duplex Building

2) **SEMI-DETACHED DWELLING**

The problems arising from land availability encourage the development of these types of residencies in Lagos metropolis. The semi-detached dwelling units usually occupy the same areas as single family dwelling but with two family occupants sharing party wall. The issue of party wall sharing therefore call for more better understanding of bioclimatic principle, for purposes of ventilation and indoor air quality. Scarcely do the numbers of internal spaces requirements differ from the single family detached dwellings, so also the occupancy rate, while the number of family occupation is doubled. A typical semi-detached dwelling in Lagos metropolis is as shown below in PLATE 2.2, FIGS. (2.2a, b and c).

PLATE 2.2 Semi-Detached Duplex at Amuwo-Odofin

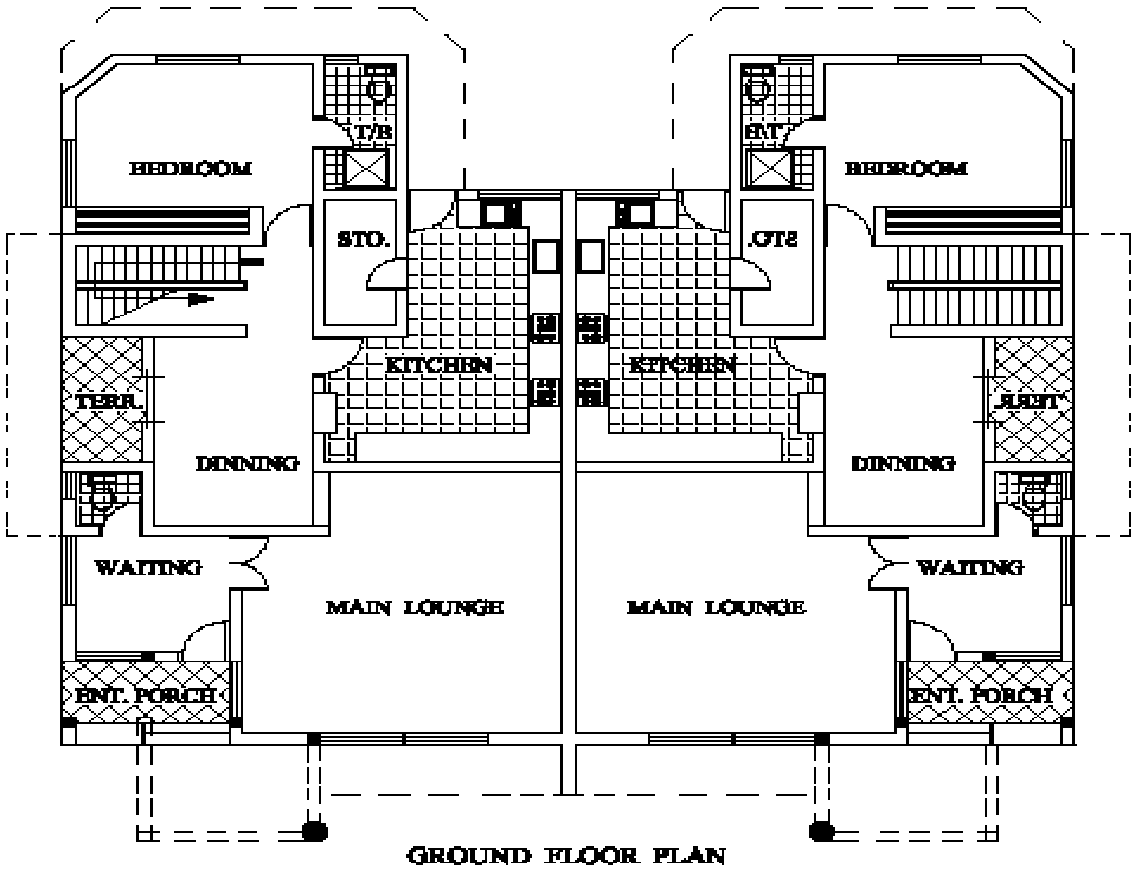


FIG.2.2a Ground Floor Plan of a Typical Semi-Detached Building

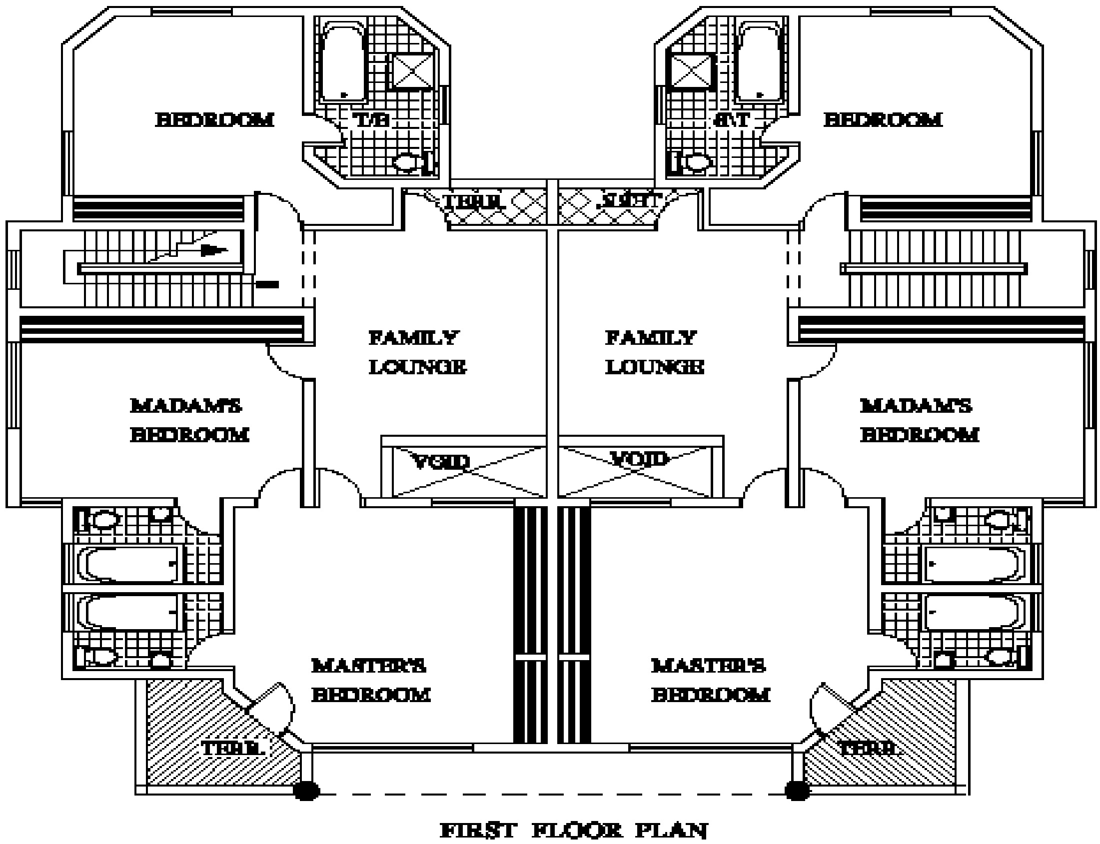


FIG.2.2b First Floor Plan of a Typical Semi-Detached Building

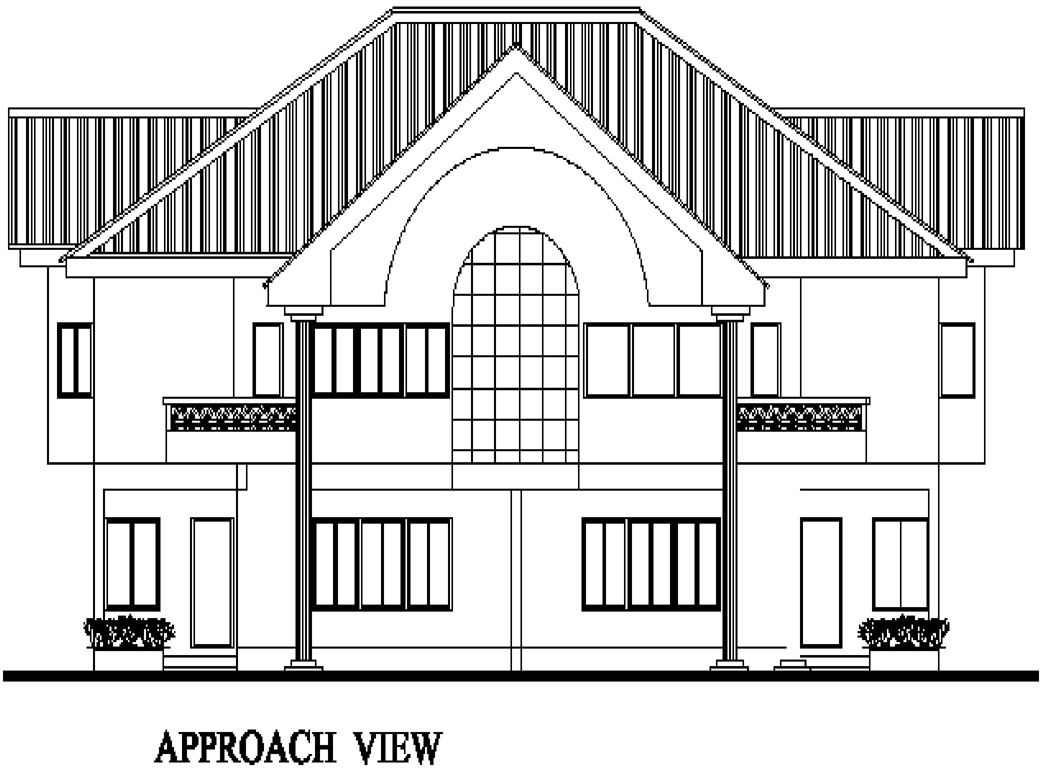


FIG.2.2c Approach View of a Typical Semi-Detached Building

3) MULTI-FAMILY RESIDENTIAL UNITS

The multi-family residential dwelling units in Lagos metropolis includes, Terrace Houses, Block of Flats and Face-to-Face units as found in different parts of Lagos. This type of residential units constitutes the greatest number of the population of residential buildings in Lagos metropolis, both old and newly built public and private residential housing estates.

TERRACE HOUSES

This type of residential building types are either bungalows or duplexes as found in Lagos metropolis. The two types are usually found in both public and private housing estates. A block of each of the building type consists of minimum and maximum of four and six family units respectively in row houses. In low rise housing units, they are usually within one or two and halve floors in most cases. Here also, the issue of ventilation and indoor air quality, in relation to the understanding of bioclimatic principle of design for comfort and energy requirement is very important to energy consumption.

The building blocks are in smaller family unit bays, with larger total frontage that allows for individual family access and private backyard/garden as found built. The occupation of the family units ranges between four to seven occupants in a medium income setting of Lagos metropolis. A typical family unit occupy between 4.5metre to 9metre width as shown in PLATE 2.3, FIGS. (2.3a and b) below.

PLATE 2.3 Terrace Apartment at University of Lagos, Akoka

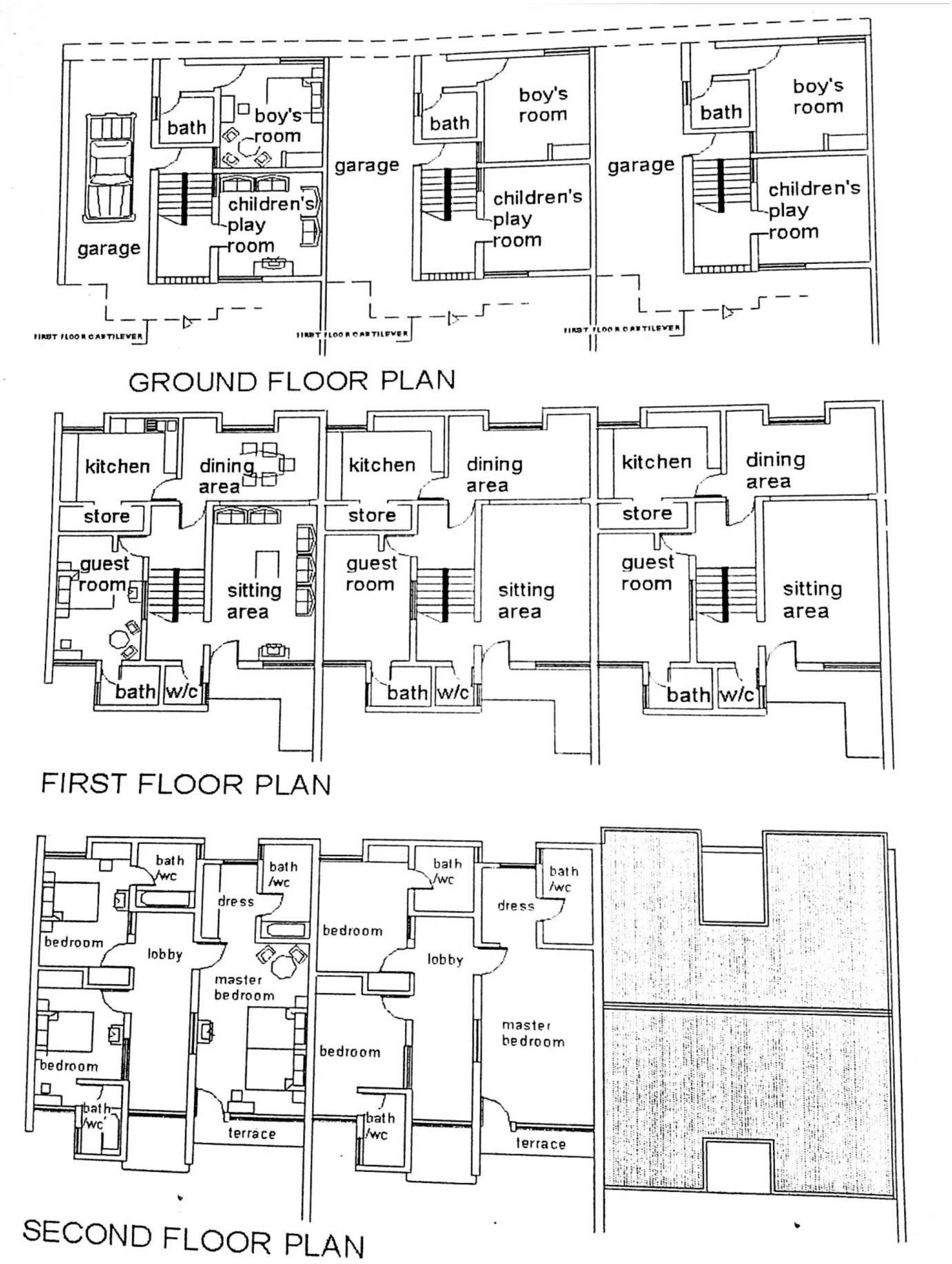


FIG.2.3a Showing Ground Floor, First and Second Floor Plans of a Typical Terrace Apartment

FIG. 2.3b Approach Elevation of a Typical Terrace Apartment

BLOCK OF FLATS

This type of residential buildings in Lagos metropolis represents a highest population of buildings. They are usually occupied by renters and younger working group of the population. This building block type occupies minimum of four to six family units of low rise housing on four floor levels. They usually share a common staircase to access their apartments from the ground to last floor. They can be found in both public and private hosing estate schemes, occupants are usually tenements apartments units, while family population ranges between four and seven number occupants. A unit flat are either two, three or four bedroom units depending on their locations, land availability and return on investment. See PLATE 2.4, FIGS. (2.4a, b and c) below.

PLATE 2.4 Block of Flats at Eti-Osa

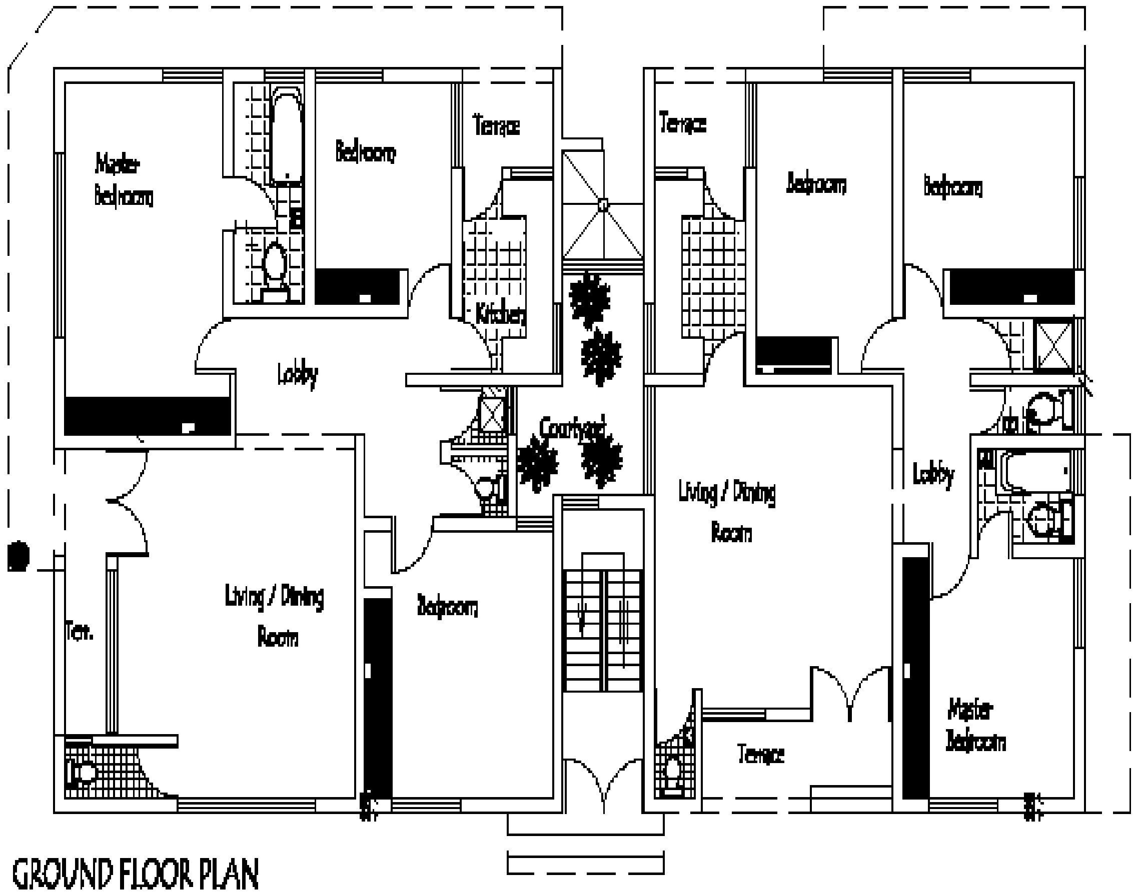


FIG. 2.4a Ground Floor Plan of a Typical Block of Flat

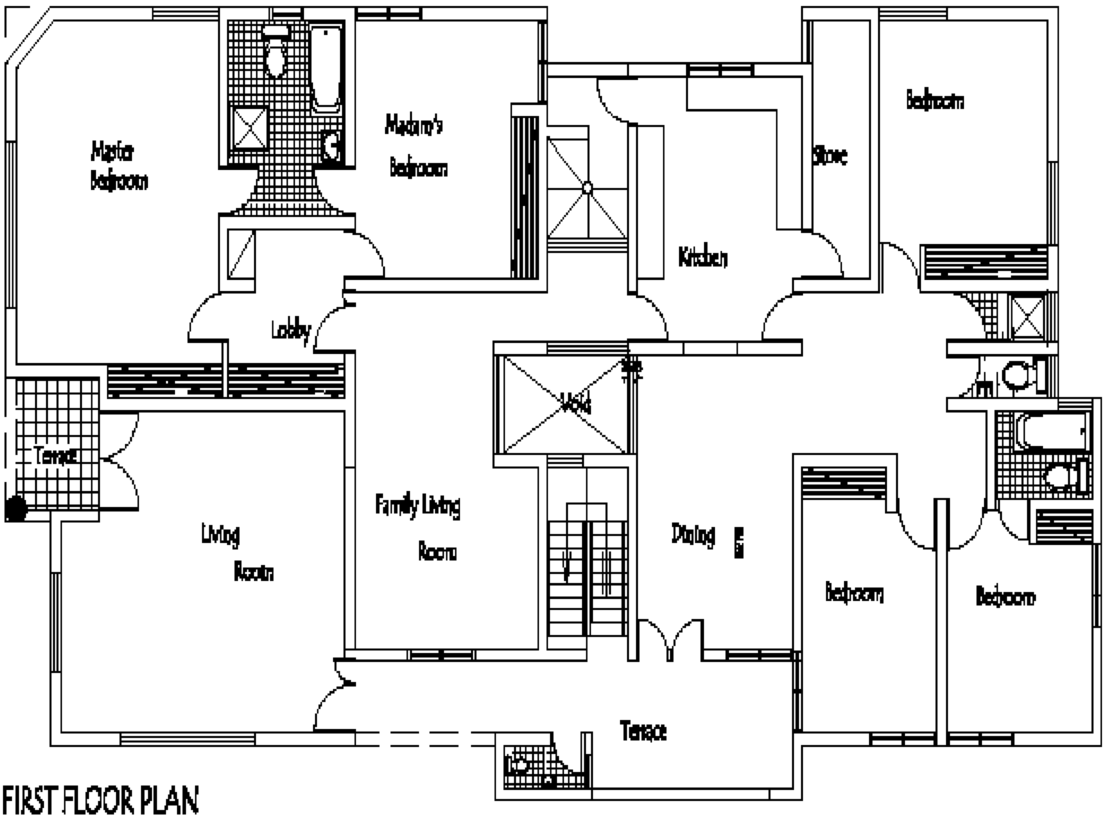


FIG. 2.4b First Floor Plan of a Typical Block of Flat

FIG. 2.4c Front Elevation of a Typical Block of Flat

FACE-TO-FACE HOUSES

These types of residential buildings or tenement houses are low cost housing units in Nigeria and Lagos in particular. It consists of a group of one to three bedroom apartments, having their entrances facing each other with bathroom, toilet(s) and kitchen spaces usually shared. Rooms are arranged as double bank corridor access to rooms and facilities. Usually consisting of a minimum of eight rooms to maximum of sixteen bedrooms with shared facilities including energy source. These types of building are also built on maximum of three floor occupant units. While ventilation and indoor quality remains their major problem as they share one source of electricity supply. Most common to this type are the bungalow units, as most of them are fixed with air-conditioner units, as seen in the PLATE 2.5 and 2.6, FIGS. (2.5a and b).

PLATE 2.5 Face-to-Face House at Shomolu

PLATE 2.6 Face-to-Face House at Mushin

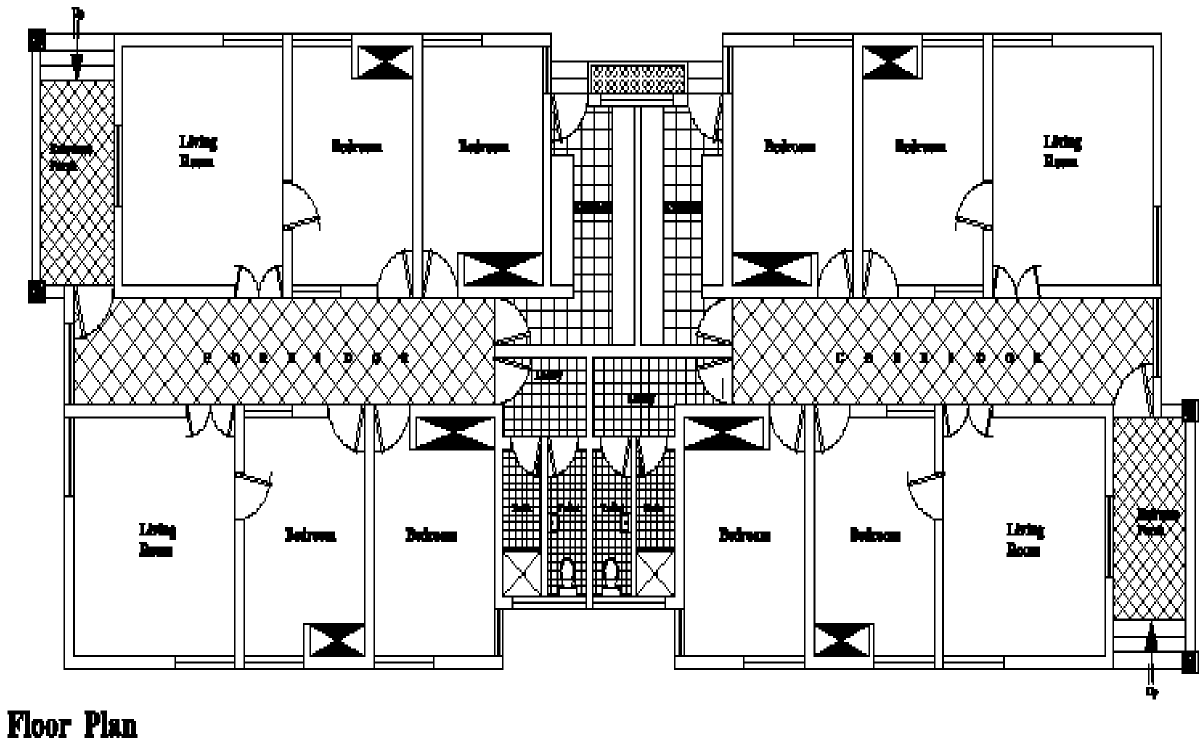


FIG. 2.5a Floor Plan of a Typical Face-to-face

FIG. 2.5b Approach View of a Typical Face-to-face

Energy consumption of residential building types has not been identified as an indicator that influences or determines the rate of energy consumption in the households. Rather the type of occupancy rate or population has been found to be significant in energy consumption in most studies.

2.1.2 BUILDING PLANNING AND LAYOUT

The basic passive principles for energy efficient residential buildings established that **Planning** and **Building Envelope** elements are vital considerations that explain building characteristic contributions to energy consumption. The study of Sigit and Orama (2015) shows that the concept of Urban Heat Island (UHI), mitigation and adaptation planning and energy efficient housing design will contribute to better solutions for a more energy efficient city.

Planning therefore consists of three major interdependent components. These components are necessary for consideration since they all affect energy consumption in different ways. They include:

- Site Analysis and Building Orientation
- Landscape and Building Location
- Building Form and Room Orientation

These are design specifics that have been found to be necessary considerations at project inception for integrated building design by owners and the built environment professionals.

2.1.3 SITE ANALYSIS AND BUILDING ORIENTATION

The proper planning at the micro and macro levels involved in an integrated design gives considerations to natural site constraints and opportunities towards the attainment of a sustainable built environment through proper building orientation. Given this consideration, issues involving site topography, wind directions, natural water, trees and green and all other physical objects within and around site are required for analysis. These analyses are very important in energy consumption, as differences and balances achieved in terms of Landscaping are given large measure of significance. The energy use is affected by choices of percentage area of soft scape and hard scape around built up spaces in site, for effective control of direct solar radiation and irradiation of surfaces on internal environment of buildings.

Wind breaker may not be needed in tropical climate, since it impedes desirable breeze. However, it is more desirable to have good air movement in and around built environment for ventilation purposes. This is premised on the comfort of the occupant and likely behavioural actions to be taken toward attainment of this and the energy implication as well. However, dense housing developments and proliferation of built structure hinder the scope of choosing portions of site without windbreaks in Lagos. For this reason, and together with the violation of planning regulations in respect of building sets back for air spaces, problem of urban heat islands has been the order of the day.

BUILDING ORIENTATION

The consideration for a proper building orientation specifically differentiates the building characteristics in terms of the building's exposure for warm humid indoor comfort environment. This plays a vital role in the determination of energy consumption rate of buildings.

According to Gut and Ackerknecht (1993), the longer axis of the buildings should be along east-west direction for minimum solar heat gain by the building envelope. This is because good orientation of buildings takes advantage of solar and prevailing wind to determine the thermal comfort of occupants at all time. This at the same time can positively or otherwise determine their energy consumption rate.

Wong and Li (2007), in a Singapore tropical climate performed field measurements and computational energy simulations to examine the effectiveness of passive climate control methods such as buildings orientation in residential buildings of Singapore. Their result indicates that the best orientation for a building in tropical climate such as Singapore is for the longer axis of the buildings to be along east –west direction. They also conclude that the cooling load for residential buildings can be reduced to 8% -11% by following the building orientation in tropical climate. The settlement pattern and most layouts planning in Lagos metropolis do not favour this orientation, which constitute a major limitation for designers. Thus, this poses a serious challenge to a designer who wants to achieve east – west orientation. Consequently, this results in overheating and poor ventilation, thereby encouraging the use of air conditioners which would increase energy consumption in the study area.

2.1.4 LANDSCAPING AND BUILDING LOCATION

The landscaping characteristic effect on energy consumption is explained by elemental component coverage areas around buildings location with regard to the percentage area of available trees, hard and soft scape in different sites.

Racissi and Taheri (1999) noted the beneficial effect of trees in residential neighbourhoods. They stated that planting of trees can result in energy saving, reduction of noise and pollution. Their study on proper tree planting for energy saving concludes that the cooling loads of a house can be reduced by 10% -40% by appropriate tree plantation. Racissi and Taheri also assert that tree can act complementary to window overhangs, as better blocking of low morning and afternoon sun, while overhangs are better barriers for high noon sunshine see FIG. 2.6.

Simpson's and Macpherson's (1990) study aligns with that of Racissi and Taheri. and also pointed out that tree shades can reduce annual energy for cooling by 10-50% The Lagos state government's effort on tree planting and street open space Landscape is therefore highly commendable in this respect. However, implementable legislations may still be needed to complement this effort that specifies the percentage of areas covered for soft and hardscapes at residential plot development.

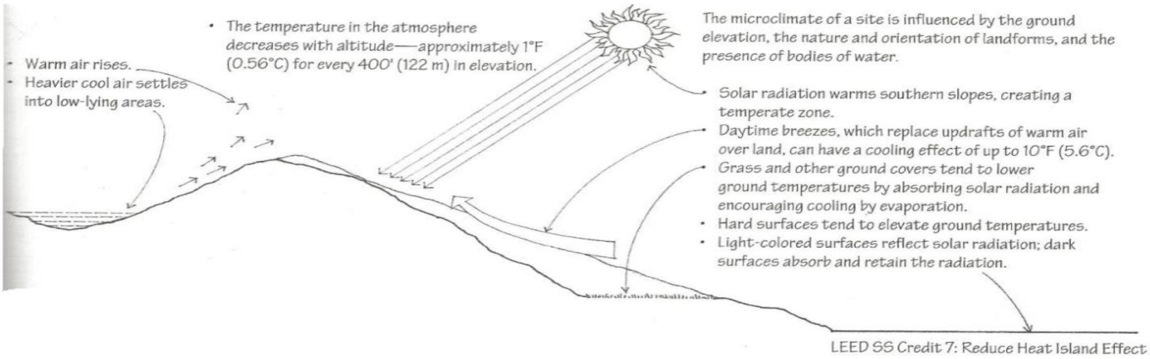
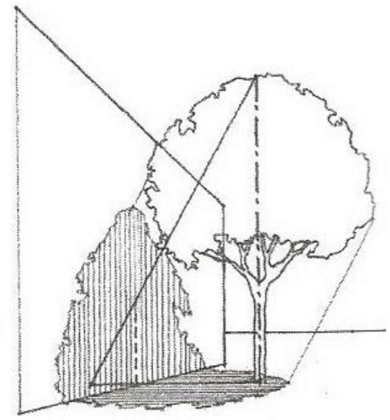


FIG.2.6 Site Landscape Characteristics

Reduce Heat Island Effect (Source: Francis D.K. Ching)

Watson and Labs (1983), posit that buildings should be placed in such a way that they cans get adequate shades from trees and landscapes. Therefore, the siting of buildings to the East of such features to reduce solar gain during afternoons when the sun is low is desirable (see Fig.2.6). In fact, the United Nations Environmental Policy UNEP (2006) warns that improper planning of site can result in the total pave area of the site and shading the paved surfaces. This effect, to a great extent, can lead to higher or lower energy consumption as the case may be in different sites and layout in cities and estates.

The criteria do not directly generate reduction in energy use, but enables the movement of air for ventilation if wind breaks are absent. This helps to keep buildings cool through the shade provided by surrounding buildings thereby, easing significantly, indoor thermal environment and likely overheating that make occupant's energy consumption less dependent on active means of supply.



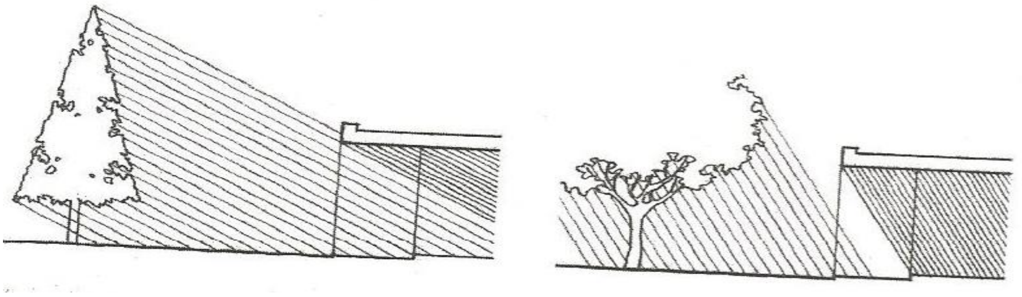


FIG.2.7 SITE VEGETATION

(*Source: Francis D.K. Ching, 2008*)

2.1.5 BUILDING FORM AND ROOM ORIENTATION

The building form and internal activities space orientation, to a greater extent, impact positively or otherwise on energy consumption, depending on the building location and orientation. Different geometrical forms also affect energy use in buildings, depending on the modes of their ventilation.

Gut and Ackerknecht, (1993), suggested forms with large surfaces rather than compact buildings. This is due to the fact that large surfaces favour ventilation and heat emission at night time. Givoni (1980) states that building form largely, depends on whether the building is planned to be air-conditioned or if it is intended to rely on natural ventilation. Therefore, he recommends a compact shape for the building occupied by people who are determined to use air-conditioners and open forms for naturally ventilated buildings.

Examining the effect of energy consumption, Voss, (2001), cited in Voss *et.al*; (2007) conclusively suggest that slender buildings provides high visual and thermally comfortable building technology and particularly without the need of mechanical cooling. Voss's study further listed orientation, shape, glassed area, thermal mass and type of facade major characteristics that determine heating and cooling energy demand as well as the possibility of use of daylight, natural ventilation and many passive cooling technologies as solutions to high energy demand for cooling.

Compactness in building minimizes the surface area of the building envelope, resulting in the reduction of heat gain through the envelopes. It may however, not be possible to design open, outward buildings in constricted sites, such as Lagos where maximum utilization of land for profit maximisation is the main objective. The Lagos land use pattern and residential layout mostly conform to the objective of maximising profit. Therefore, building compactness has become the order of design consideration. This encourages the use of air conditioners that make energy consumption a vital issue in the study area.

ROOM ORIENTATION

Depending on the activities of occupants, building modes and owner's preferences, rooms and space orientations in residential buildings play key roles in the control of energy consumption. According to Gut and Ackerknecht, (1993), the arrangement of rooms depends on their function and according to the time of day they are in use. Similarly, Watson and Labs (1983), argued that a house can be made more energy efficient if it is planned according to solar orientation and the prevailing wind direction.

It is also in this light that Givoni (1998), pointed out that cross-ventilation can be used to aid faster cooling and better ventilation, stressing that building layout which provides good potential for cross ventilation is more appropriate for developing countries in hot humid regions where majority of the people cannot afford the luxury of air-conditioners. He therefore recommended a spread out building with open able windows so as to facilitate cross ventilation.

Furthermore, Gut and Ackerknecht, (1993), commented on climate responsive buildings. They noted that in order to get an appropriate building construction in tropical and subtropical regions, bedrooms can be positioned on the eastside of the building where it is coolest in the evening. Gut and Ackerknecht aver that rooms which are used most times of the day, such as living rooms should be located on the northern side. In addition, they advised that stores and other ancillary spaces should be located on the disadvantaged side, mainly on the western sides. According to them, provided that the kitchen is used during morning and midday hours, it can be located on the West side as well.

Also rooms with high internal heat load such as kitchen should be detached from the main rooms where and if possibility exists. It is worthy of note that Auto CAD (Computer Aided design) may have initial proper orientation, but fails to meet the orientation requirement as soon as it is mirrored. These effects are common in most mass housing and expanse of estate layout of residential neighbourhoods.

2.1.6 BUILDING ENVELOPES

Building envelope is used to describe the physical components of the buildings characteristics, with respect to external walls, windows, door openings and roof to designers, owners and occupants in most time. This, to a great extent determines much of the energy consumed in the building, as their direct interaction with the external environment affects building's indoor environment. Design ability to the right envelopes material choices for construction process in attainment of optimal energy use plays a significant role in conservation and efficiency.

The building envelopes therefore, involve considerations, for material selections, process considerations, and elemental choice towards use and efficiency attainments. They include the following: External wall, Windows openings and roof.

2.1.6.1 EXTERNAL WALL

This constitutes the greater percentage of the residential building envelope in the study area. It is mostly defined by materials such as bricks sandcrete blocks, concrete and glass. Their material constituents and values, in response to external climatic environment, determine the heat of the building and consequently describe the effect of energy consumption on households.

According to Gut and Ackerknecht, (1993), the main goal in building design of tropical climates is the reduction of direct heat gained by radiation through openings and reduction of internal temperature. As they propose, buildings should be designed with protected openings and walls. Accordingly, Gut and Ackerknect argue that the outer surfaces of the external wall should be reflective and light-coloured. This position is also taken by Cheing *et al* (2005). However while Cheing *et al* align with the view of an unreflective and light-coloured external wall, they also point out in their study, the need to reduce cooling energy for high rise apartments through an improved building design. In this regard, Chieng *et al* identified six passive thermal designs strategies namely: insulation, thermal mass, colour of external walls, glazing systems, window size, and shading devices as means of reducing internal heat gain, consequently reducing energy consumption.

Furthermore, their study shows that annual cooling has an almost linear relationship to the solar absorbance (amount of solar energy that passes into a material) of the external surfaces. Energy is found to be high with lower solar absorbance, while a 30% reduction in solar absorbance can achieve a 12% saving in annual required cooling energy in buildings. Cheing *et al* (2005), therefore concluded that 12% saving on cooling energy may be obtained from using white light-coloured external wall finishing.

Mathur and Chand (2003) believe that thermal resistance of a wall can be increased by introducing an air cavity in external walls. Also, Mallrek (1996) asserts that increase in wall thickness can make a considerable difference in the comfort level of houses in tropical climate. In Lagos, massive use of cavity wall could therefore be a response to these findings, as it encourages night cooling.

Wong and Li (2007), in their study of field measurement and computational energy simulation to examine the effectiveness of passive climate control methods such as facade construction in a typical 14 storey residential building of Singapore, posited that the use of thicker construction on east and west external walls can reduce the solar radiation heat gain, hence the cooling load can be reduced by 7% -10% when the external wall thickness is doubled in 250mm concrete hollow block instead of 114mm concrete hollow block .

According to Gut and Ackerhnecht (1993), the transmittance value or U value (measurement of heat transfer through a given building material) of 250mm hollow concrete block whitewashed externally is 1.7W/m2. The U value of a 280mm brick wall (115mm brick + 500mm brick) and white washed externally is also 1.7W/m2. The likely implication of this in the study area is that both the thickness of the wall, cavity nature of wall material and U value, together with the type of paint used, might have an effect on the building energy consumption. Importantly, thermal properties of building fabrics offer different solutions to thermal control problems. However, thermal properties must be appropriately exploited in accordance with the prevailing climatic conditions. In warm climate, the essence of thermal control is to prevent overheating of buildings interiors by appropriately controlling the conducted flow jointly due to the incident solar radiation on the fabric and influence the amount of energy consumption in the household for the control of the indoor climate.

According to Koenigsberger, *et al* (1974), the value of the solar gain factor should not exceed 0.04 in warm humid climates such as the study area under consideration. Hence, absorption (or rejection) of solar radiation at the fabric surface and the subsequent transfer of heat across the fabric should be used as the thermal performance standards of building fabrics especially in climatic regions like Lagos where buildings undergo overheating due to solar radiation.

In realisation of the sensitivity of envelopes thermal performance to energy use and thermal comfort, some building materials in tropical climates were recommended for use by Gut and Ackerknceht (1993).

Burnt clay bricks can be used in tropical climates because they have good thermal resistance which is a good regulator of humidity. Others that may be used include:

1. Timber which has good thermal resistance and is a good regulator of humidity.
2. Matting of bamboo, grass and leaves which are equally good because they are air tight and allow proper ventilation,

Most of these recommended natural building materials have gone into extinct in Lagos, as they were mostly used as a native building material. For this reason many imported building materials have dominated the built environment. Many of them may not be suitable for our weather condition and might consequently have series of energy consumption implications. This is because of the cost involved in seasoning timber, while bamboo, grass and leaves are building materials that are not use in an urban setting any longer.

Many researchers conducted on external envelopes in handling thermal effect on external wall performance, suggest wall thermal insulation as vital solution to the problem of radiant heat conductivity, as it impact on energy consumption. Bolatturk (2008), Cheing *et al* (2005), Mathur and Chand (2003), Yang and Hwang (1993), Gut and Ackerknecht (1993) and Koenigsberger, *et al* (1974).

According to Bolatturk (2008), thermal insulation is one of the most effective energy conservation measures for cooling and heating in building because it reduces heat transfer to and from the buildings. This view seems to conflict with those of Gut and Ackerknecht (1993), and Yang and Hwang (1993), which state that thermal insulation has very little efficiency in warm-humid zones because the ambient air temperature inside and outside the buildings is the same due to the free flow of air. Corroborating this view, Yang and Hwang (1993), also note that thermal insulation has a dual nature. It reduces daytime excess heat entering a building, but averts the building from cooling down at night. For this reason of dual nature therefore, insulation might be unsuitable for buildings like mix mode, with natural climate control that is warm and humid, as can be found in the climate of the study area. It becomes necessary then to arrive at a consensus. This consensus lies in first determining the cooling load at the stage of designing the building. It also lies in going further to decide whether the cooling load can be reduced by employing thermal insulations at buildings or using passive means of control or a mix mode.

Tham's (1993) study of various energy conservation strategies obtained results that do not encourage wall insulation. The study concludes that by adding 50mm of polystyrene as wall insulation, only 1.7% reduction in total energy use is achieved. He therefore suggested that if savings in operational cost were compared to the cost of installation, wall insulation would not be economically feasible. Adding a new perspective to insulation, Givoni, (1990), points out, in relation to this work, that in Bioclimatic architecture, the technology that supports insulation in the study area is not readily available, hence, the application of insulation may not be advisable.

Olufowobi's (2009) study aligns with the view that the thermal behaviour of the buildings fabric in the study area depends on the thermal capacity, the U-value and the solar radiation absorptivity. He posited that heat gain through walls usually constitute only a small fraction of gross sensible heat in building which further makes wall insulation unnecessary. This is because high percentage of heat gain is through the roofs which are directly exposed to solar radiation in most instances.

2.1.6.2 WINDOWS AND OPENINGS

The importance of this multifunctional building characteristic element makes it more significant to energy consumption in the residential buildings with regard to striking a balance between ventilation and natural lighting. This is in reference to their type, size, locations and building's orientation of the envelopes fabric as shown in Figures 2.8 and 2.9. The research findings of the element measure its relevance to solar conductivity, thermal comfort and subsequently impact on energy consumption.

Openings are important design element for admitting daylight, airflow, providing cross-ventilation and views. Gut and Ackerknecht (1993), recommended that windows of buildings should be large and fully open-able, with inlets of similar sizes on opposite walls for proper cross – ventilation in tropical climates. In the study area this window varies according to the owner's desire for cost and aesthetics reasons. According to Liping *et al* (2004), ventilation and indoor air quality can be improved by increasing the window to wall ratios (WWR).The solar heat gain would be increased if this is done. This has always been an area of conflict in most designed buildings, but usually been resolved through detailed study of energy requirement and targets for different buildings. But keonil and Nopadon (2012) study shows that ventilation manipulation alone hardly lower room temperature in high humidity condition.

Liping *et al* (2007) also carried out an optimised and comprehensive evaluation by using building simulation and indoor CFD (Computational Fluid Dynamics) simulation for an accurate prediction of indoor thermal environment and for naturally ventilated buildings in the hot humid climate of Singapore. The window sizes in this coupled simulation was made to vary from WWR = 0.1 to WWR = 0.4 for all orientations. The result shows that the optimum window to wall ratio is equal to 0.24 and horizontal shading devices are therefore needed for the four orientations, especially for large windows. Mathur and Chand (2003) argue that for rooms in which identical windows are in opposite walls, the average air speed increases rapidly with increase in the width of window, up to 2/3 of the wall width. Moreover, the increase in air speed is in much smaller proportions as shown in Fig.2.9.

WINDOWS ORIENTATION

This plays a major role in energy consumption, as different orientation of windows admit different level of radiant heat into the building interior. Consequently, they determine the level of thermal responses of the building interior climate and occupant's thermal comfort with the use of available control means to ameliorate their condition.

On windows orientations, Gut and Ackerknecht (1993) note that openings in hot and humid regions should be placed according to the prevailing breeze so that air can flow through the internal space, but could be very difficult in multi-unit housing. While Ahmed (1987), in her study of the effects of climate on the design and location of windows for buildings in Bangladesh, notes that orientation of windows should be avoided on western walls, as it is almost impossible to shade in all seasons. Liping *et al* (2007) also emphasizes the avoidance of east or west facing rooms for the purpose of thermal comfort and energy use. The nature of warm humid in the study area may not have been much different as air is mostly vapour-laden, while opening orientation favours eastern and south west orientation for thermal comfort and airflow. According to FIG. 2.9, high direct airflow upward results in the loss of cooling effect, as low level air inlet location directs airflow at occupants. This is mostly determined by pressure differential which are employed in bioclimatic tropical design principle for low energy in mixed mode buildings.

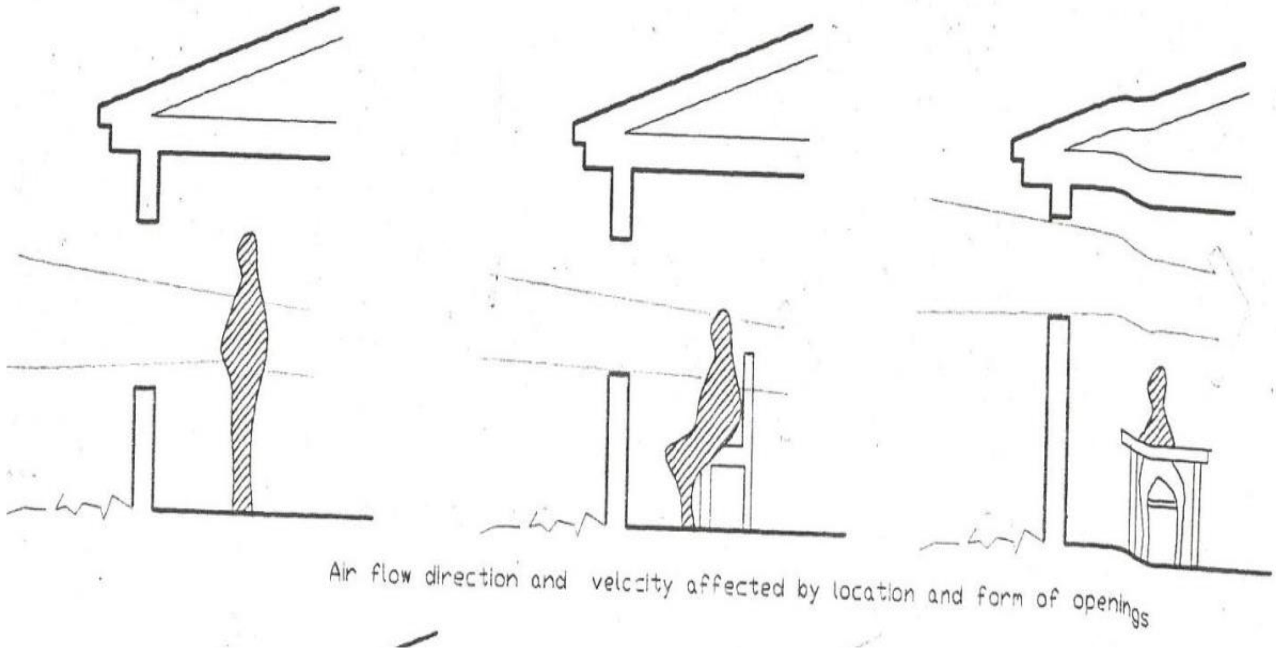


FIG. 2.8 Airflow direction and velocity affected by location and form of openings

(Source: Francis D.K.Ching, 2008)

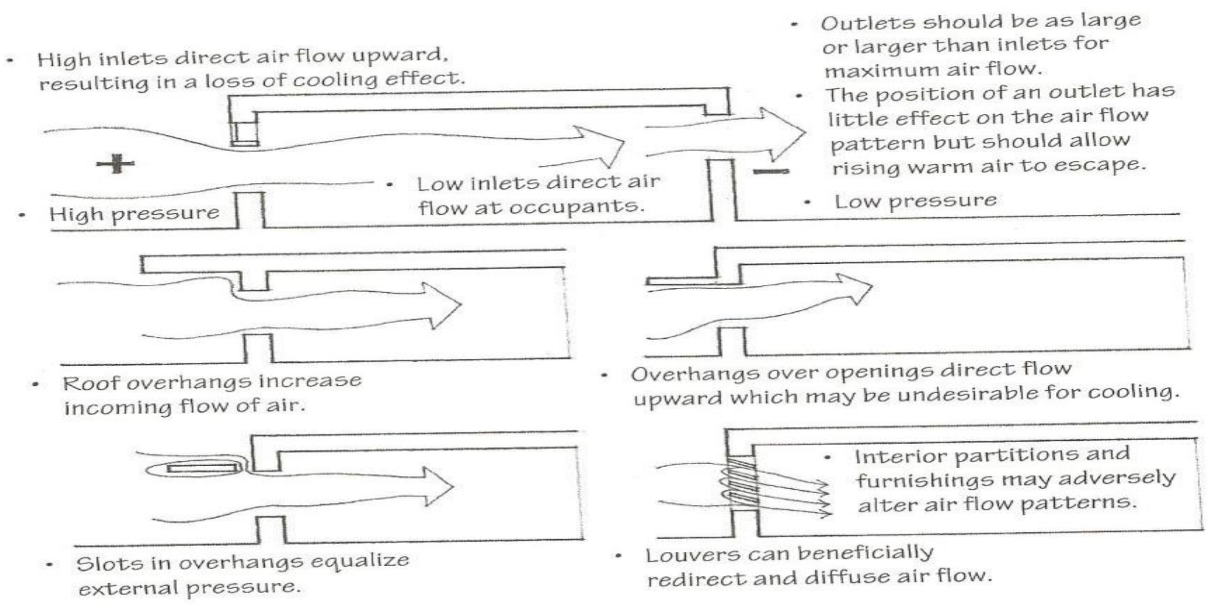


FIG.2.9 Window Sizes on Increased Ventilation,

(Source: Francis D.K. Ching, 2008)

2.1.6.3 ROOF

The roof is an important design element for energy conservation and efficiency attainment in building. It receives most of the solar radiation and its shading is not always easy. Roof is responsible for about 25% of heat loss (Fig.2.25) from the building interior, as it protects buildings from environmental harsh conditions. Its type and eave overhang extent contribute positively to saving in energy consumption. Kumar et al (2007) reveal that Indian concrete roofs in single or two storey buildings with 150mm thickness of reinforce cement concrete (RCC) and a weathering courser (WC) having 75 -100mm thick line brick mortar, account for about 50% -70% of total heat transmitted into the occupant zone. They are also responsible for the major portion of electricity bill in air conditioned buildings

Nathan and Sharma in Tang and Etzion (2004), Vijay Kumar *et al.* (2007), Alvarado and Martinez (2008) conclude in their studies that the heat entering into the building structure through roof is the major cause of discomfort in case of non-air conditioned building or the major load for the air conditioned building. However, Gut and Ackerknecht (1993), argue that this is only true for single storey buildings and the top of multi-storied buildings such as in Lagos, where most residential buildings are low rise with much smaller roof area than the external walls. Therefore, here the conduction heat gain through the roof in Lagos is likely smaller than that through the external walls and windows. However, Olufowobi (2009) study reflected an interesting finding, which concludes that a high percentage of heat gain is through the roofs which are directly exposed to solar radiation. This is as presented in the analysis of the heat transmission characteristics of both pitched and flat roofs with different materials in the study area, as shown in Table 2.1.

The study concludes that the thermal behaviour of a building, as determined by the overall thermal performance of its fabrics, has a significant influence on the amount of energy required to cool a building interior. In the same vain, solar radiation plays a major role in the overheating of building interiors in the tropics such as Lagos.

The U-value alone seems not to be adequate in influencing and indicating the true thermal response of an opaque building fabric exposed to high solar radiation intensity. Therefore, the advice is that in warm climates, it is more appropriate to use absorptivity value as an indicator of thermal performance of roofs and walls. It further recommends that roofs and walls must be specified such that their XU values do not exceed 0.8W/m^2deg.C.

TABLE 2.1 RECOMMENDED ABSORPTIVITY VALUES FOR ROOF CONSTRUCTION

A. **Pitched Roofs**	**@**	**U W/m^2degC**	**αU W/m^2deg C**
Corrugated a/c Roofing sheets (no ceiling)	0.65	6.1	3.97
Corrugated a/c roofing sheets above 5mm a/c ceiling Sheets	0.65	2.31	1.50
Corrugated roofing a/c sheets above 13mm Fireboard ceiling.	0.65	1.70	1.11
*Corrugated a/c sheets above 13mm fireboard + aluminium foil.	0.65	1.20	0.78
*Corrugated iron sheets (new) above 13mm Fireboard ceiling.	0.55	1.30	0.72
Corrugated iron sheets (new) above 5mm a/c ceiling Sheets	0.55	1.90	1.05
*Corrugated a/c sheets above 5mm a//c boards + 25mm fibre glass + aluminium foil	0.65	0.80	0.52
*Corrugated aluminium sheets above 5mm a/c boards	0.3	1.90	0.57
Painted (brown, red, green) corrugated aluminium Sheets above 5mm a/c boards	0.7	1.90	1.33
B. Flat Roofs			
100mm reinforce concrete slab, 12 – 63 mm screed, 3 Layers bituminous felt	0.90	3.35	3.02
As above with 25mm cork insulation on screed.	0.90	1.08	0.97
*Corrugated aluminium sheets on 100mm reinforce Slab	0.30	1.30	0.48
*Corrugated aluminium sheets on 100mm reinforced Slab, 75mm cement screed, 18mm plastering.	0.30	1.23	0.37

Source: Olufowobi (2009) study of Roof thermal Performance in Lagos Nigeria.

TABLE 2.2 RECOMMENDED ABSORPTIVITY VALUE FOR WALL

Walls			
105mm solid brick, 16mm unplastered	0.7	3.64	2.55
105mm solid brick, 16mm plaster on inside surface	0.7	3.24	2.27
220mm solid brick unplastered	0.7	2.67	1.87
220mm solid brick, 16mm plaster on inside surface	0.7	2.44	1.71
105mm solid brick wall unplastered with 10mm Plaster- board lining fixed to brickwork	0.7	2.80	1.96
220mm solid brick wall unplastered with 10mm Plaster-board lining fixed to brickwork.	0.7	2.0	1.40
228mm hollow sand Crete block wall plastered on both Sides	0.5	2.20	1.10
228mm hollow sandcrete block wall plastered on both Sides and painted on the outside in red, or green or Brown.	0.7	2.20	1.54
*As above but painted white on the outside	0.3	2.20	0.66
Pre-cast 75mm thick concrete wall	0.65	4.3	2.80
*Pre-cast sandwich panel comprising 75mm dense Concrete, 25mm expanded polystyrene and 150mm Light weight concrete.	0.65	0.72	0.47

Source: Olufowobi (2009) study of Walls thermal Performance in Lagos Nigeria.

Note
*Indicate construction of acceptable thermal performance.

In terms of roof shapes, Gut and Ackerknecht (1993) note that warm-humid regions should have pitched roofs so as to drain off heavy rains. This is always the case in the study area, for majority of the existing residential built up areas, as reflected in the field survey carried out. They also suggest that roofs should have large overhangs to protect the wall and openings from radiation and precipitation. This is not the usual practice in Lagos. Gut and Ackerknecht

also point out that the roofs of buildings should be made of lightweight materials, while inadequate setbacks of building are prevalent in most residential neighbourhoods.
They, in addition, claim that roofs cannot be kept cool if there are any obstructions that prevent the airflow along the roof surfaces. They recommended that parapet walls along the roof should not be high and solid and should not create a stagnant pool of hot air. But their recommendation however does not specify any height measurement that could be appropriate in different climatic regions as this study does.

Alvarado and Martinez (2008), studied the impact of a simple and passive cooling system in reducing thermal loads of one storey roofs. Their result demonstrated that aluminium-polyurethane insulation system with an optimal orientation reduces the midpoint temperature of a cement- based roof significantly. The result also reveals that the roof insulation system can reduce the typical thermal load by over 70% while effectively controlling thermal fluctuations.

Garde *et al* (2004), and Suehreke *et al* (2008), however, realised that in tropical climates, intermediate roof insulation can only decrease the air temperature inside a dwelling by few degrees. Suehreke *et al*, therefore, conclude that roof insulation may hinder the desired night time cooling, but the study area does not practice insulation in the roof, even though the warm humid nature might not have encourage this.

Akbar, in Kumar *et al* (2007) has shown that passive roof cooling systems like coating the roof top with highly reflective coatings can reduce the heat transmission across the roof by 20%- 70%. But the deterioration of roof coating reflectivity over time is a major setback. However, for dust-prone, tropical countries, the cooling benefit of a roof surface with high solar reflectance can decrease with time as the surface accumulates dust and other environmental deposit. Levinson *et al* (2005), however, suggest that washing the dirt off the reflective roofs can almost completely restore its original reflectivity.

GREEN ROOFS

These have been severally investigated to determine how they could improve the quality of the urban environment. Teemusk and Mander (2009) described Green Roof as consisting of the following layers; A) A waterproofing membrane; B) A drainage layer; C) A filter membrane; D) A substrate layer and plants

The composition and thickness of this substrate layer is however decisive. The benefits of green roofs as noted by Teemusk and Mander (2009) are many.

Wong *et al,(*2003), in their study of life cycle cost analysis of rooftop gardens in Singapore, state that despite the availability of material and suitability of climate in Singapore, many developers are often held back from rooftop garden in design brief mainly by concerns pertaining to cost. Their calculations show that only extensive green roofs bring about net savings. The findings of Wong *et al,* (2003) imply that the initial cost of roofing gardens vary with the type of structure and on the selection of planting placed on the rooftop.

The simulation results of the study they conducted however reveal that an extensive green roof could reduce energy use of the building and achieve a net cost savings of 14.6%, while the net energy savings of intensive green roof is not more than 4% and is therefore not significant. Wong *et al,* (2003) conclude that by considering these energy savings, extensive green roof does not cost more than conventional flat roof. Patterson in Wong *et al* (2003) also retracted that even though first cost of green roof range from 3-6 times, the cost of a typical roofing system, in the long term green roofs may be less expensive and outperform conventional roofing. Lippiat and Boyles (2001), reacting in favour of green roofs, note that a short- lived, low first cost product is often not the cost- effective alternative.

Despite all the benefits of green roofing, as discussed, there are disadvantages as well. Gut and Ackerknecht (1993), identified the following disadvantages of green roof;

A) They add a heavy load on the roof structure

B) Reliable water proofing of the roof is not easy to achieve.

C) Roof garden reduces heat emission at night

D) Draining channels and outlets may get clogged

E) High water use of roof gardens should be considered with scarcity of water.

From the discussions above, it can be concluded that extensive green roof are more energy efficient than intensive green roofs, but are inaccessible. Considering the maintenance culture, green roof maybe a limited option of energy efficient design feature in the context of Lagos, Nigeria.

Wong and Li (2007), examined the effect of introducing a special secondary roof to a 14 storey residential building in Singapore. A thermal insulation effect was thus achieved by blocking direct sunlight with the top slab and by the airflow between the concrete roof and slab. Their study showed that this kind of special secondary roof can reduce 11.59% of the cooling load. Kumar *et al* (2007) demonstrated another concept of special roof in which hollow clay tiles (HCT) are laid over Reinforced cement Concrete (RCC), instead of weathering course (WC). Through the study of four types of roof applications in Indian Tropical climate conditions, they recommended the use of Hollow Clay Tiles (HCT) in place of weathering course for roofs. Kumar *et al* claimed that the use of such a system can save 18% -30% of energy use in an air-conditioned building. These studies might be useful for high rise residential buildings which are outside the scope of the study.

2.2 ENERGY CONSUMPTION IN RESIDENTIAL BUILDINGS

In developing countries, energy consumption has been increasing rapidly due to economic growth and development of infrastructures, Building Energy Standard (B E S) (HKU) 2010, Jarda and Bush (1994). This can be attributed to the number of new buildings, rapid growth, un-encouraging energy prices and market for the use of efficient technology Hui. (2000). The International Energy Agency (IEA 2004) report pointed out that worldwide, households consume about 1/3 of the total end use energy. Most of the projected growth in energy consumption is said to occur in Asia and Africa where climate change impact is leading to decrease in energy demand in the coldest region and increase in the warmest regions.

As prior studies point out, energy consumption in buildings worldwide accounts for as much as 45% of primary energy resources. This makes building the biggest single contribution of total energy consumption according to Chow, (2011); Publish Group, (2008);Yang *et al*, (2008);Radhi, (2008); Lombard *et.al.*(2008); Omar aid and Yan *et.al* (2006),and Mohammed (2004).The studies of Hassan 2008,EC, 2007, Geoffrey & Yan kelvin, (2003), note that global contribution of buildings towards energy consumption, both residential and commercial have steadily reached figures between 20% and 40% in developing countries. Sureh *et.al.* (2011) study indicated that US residential buildings account for more than 20% of total energy consumption. But European and Asian countries" consumption is up to 30%. It is noted that the energy consumption of African countries cannot be adequately accounted for. This is mainly due to the absence of data, a fact confirmed by IEA, (2004) report. Pleongeham *et al*, (2006) study reveals that residential buildings in South Korea consume more than 55% of energy use. According to research publications on households energy use by end-use survey among 19 countries of IEA (2008) (See Fig 2.10), it is now generally agreed that buildings use energy for heating and cooling, lighting, Ventilation, Water heating, and for operating equipment and appliances.

This pattern of consumption is said to be however strongly influenced by the activities that occur within several building types, energy cost and economics. Fundamental as well is the energy use pattern that characterizes the regional prevailing climates, available technology and sources of supply. This study is mainly focused on a regional climatic setting characterized by its warmness and humidity and the three major uses of energy consumption considered include: Cooling Lighting and Ventilation.

Lang, (1999) refers to building energy consumption as the energy consumed within buildings, including the energy consumed through heating, ventilation, air -conditioning, illumination, electrical equipment, hot water supply and cooking. According to Lang, this energy consumption is related to the quality of life. As standards of living improve, Lang concludes that energy consumption in building will increase.

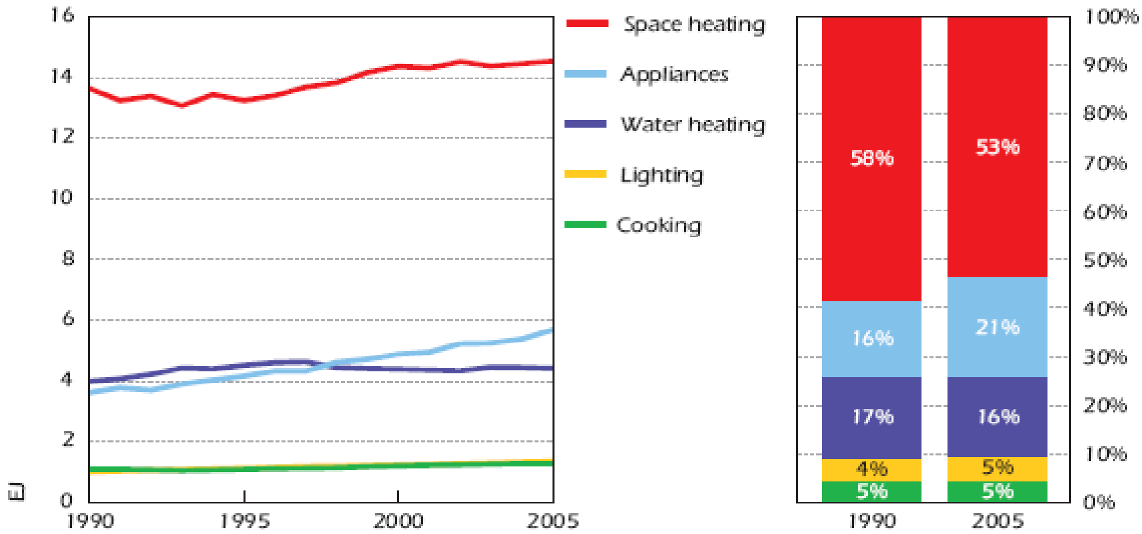


FIG.2.10 Household energy use by end-use, among the surveyed countries of IEA 19. *(Source: IEA, 2008).*

2.2.1 COOLING ENERGY CONSUMPTION

In most tropical buildings, air-conditioning system is found to be essential in maintaining good thermal environment. It is often regarded as the largest consumer of energy in which about 30%- 60% of the energy is used for cooling and dehumidification purposes.

Morna *et.al,* (2008) wrote on modelling global residential sector energy demand for air-conditioning and heating in the context of climate change and energy efficiency. Their study noted that residential heating and cooling (air-conditioning) potential development of energy use in global energy demand are projected to increase until 2030 and then stabilized. In the same way, energy demand for air-conditioning is projected to increase rapidly in the period between 2000-2100, as driven by income growth. The impact on cooling (air-conditioning) energy demand is found to increase by72%. Mor na *et.a* (2008) also found out that cooling increases with statistic collected by (IEA) for U.S and Europe. The US department of energy data book (2006) reported energy consumption through air conditioning for residential buildings to be only 10.4kw/m^2 nationwide. Similarly, that of residential buildings in Japan is less than 3.8kwh/m^2 in the same year.

Godwin, (1988) maintained that generally the study area of Lagos in Southern Nigeria enjoys good climate and may be described as moderate, having no extremes of heat and cold. In this area, the designs could be passively cooled without the need of active energy. However, Sangowawa *et al* (2006) in their study concluded that the use of air conditioning in Lagos is inevitable. They noted clearly that attempt can only be made to reduce the energy consumed by the system.

At the same time, Adebamowo *et al* (2007), in their study of low energy design in the study area, justified the use of air conditioning in Lagos. They also identified the problem of dust-Laden atmosphere of Lagos and the prevailing noise and vehicular pollution in the high density city for use of air-conditioning. This is in addition to high humidity reaching over 80% in the morning, and rarely dropping below 65% in the afternoon. While minimum temperature occurs in the evening and early morning, the afternoon comes with high temperature and consequently requiring high demand of energy to ameliorate the condition.

They further put the typical heating calculated for residential building in Lagos as corresponding to a cooling load between the ranges of 100-175W/m^2.

Horner (1998), in his study according to Voss *et al* (2007),revealed that building technology accounts for up to 20-30% of investment cost, with lower usable spaces and uses the largest part of energy consumption. Aligning with this, Pathen*et.al*, (2008), study on UK domestic home air-conditioning reveal that different type of air conditioner units affect energy consumption, depending on the average indoor temperature setting. The study show that an overall Energy Efficiency Ratio (EER) of 5-10% was revealed by single split units, while less than 1% was found for portable units tested. This could mean that the type of air conditioner, temperature setting, and average operation duration are responsible for cooling load and consequently energy consumption in buildings.

The work of Hwang *et* al; (2008), suggested that the temperature setting for air conditioning system can be raised to 2^oc higher than conventional setting for reduction in energy consumption, where every 1^0c increase in the most start setting may lead to a reduction of 6% in energy consumption according to Ayinsley, (2007) study.

In summary, achieving energy efficiency in building, with reference to cooling, will require the integration of energy use and indoor climate aspects into the very beginning of the building planning process to establish a benchmark of energy consumption.

2.2.2 LIGHTING ENERGY CONSUMPTION

End use energy for lighting in buildings can either be active driven or passive as the case may be. Passive energy for lighting in buildings usually refers to a day lighting system which is nature-driven.

A day lighting system has a number of elements, most of which must be incorporated into the building design at an early stage. This can usually be achieved when considerations are given in relation to the incidence of day lighting on the building

These may include:

1 - The orientation, space organisation and geometry of spaces requiring Lighting.

2 - The location, form and dimensions of the opening through which daylight will pass.

3 - The location and surface properties of the building's internal partitions which may reflect the daylight and play a part in its distribution.

4 - The location, form and dimensions of movable or permanent devices which may provide protection from too much light and glare.

5 – The light and thermal characteristics of glazing material used in the building.

These are further explained in FIG. 2.17 below

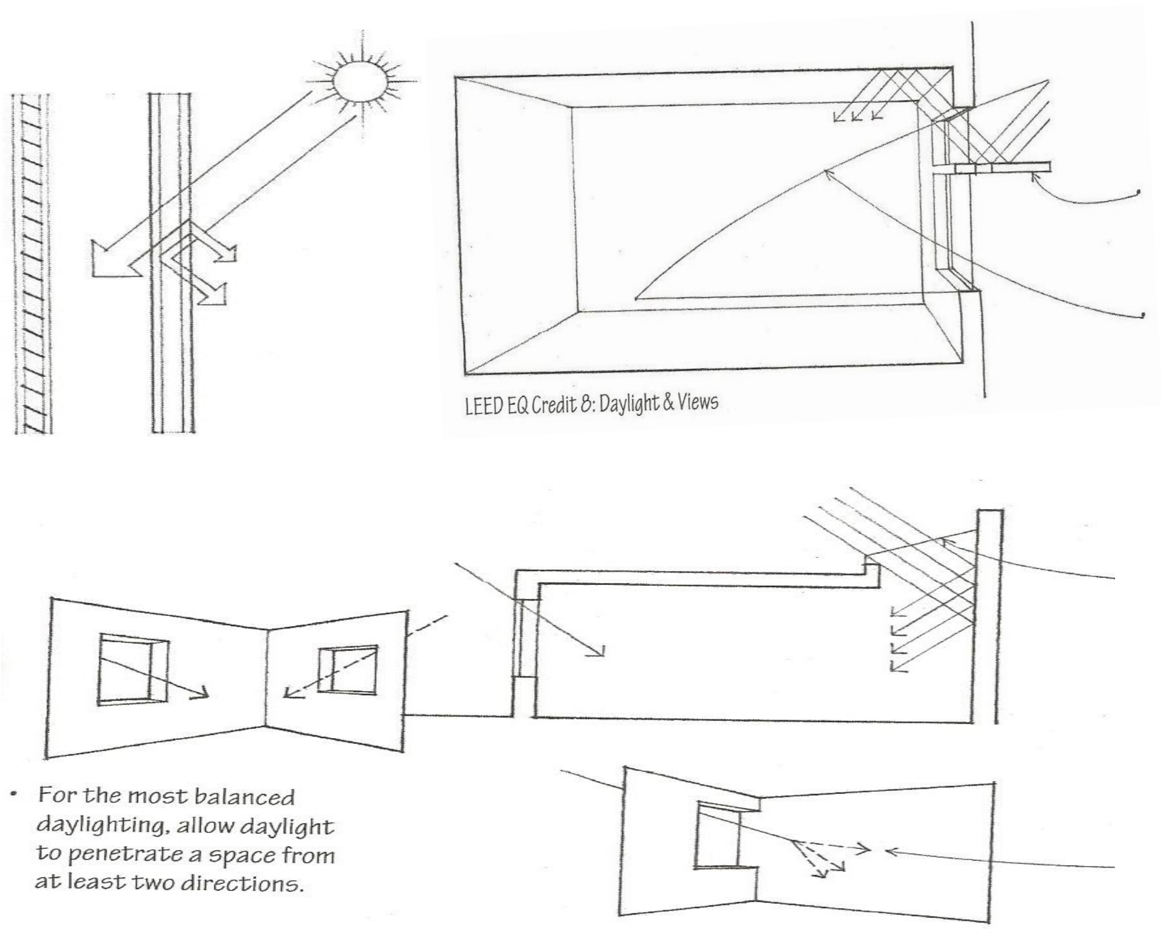


FIG. 2.11 Exterior Sun Control Devices

Source: Francis D.K. Ching, 2008

These considerations were based on a study of an office room carried out in Athens, London and Copenhagen. The finding indicated that artificial lighting almost represents about 35% of the total lighting, cooling and heating cost throughout a year. In essence, it implies that correct day lighting will reduce energy consumption in relation to artificial lighting. This could diminish the possibilities of having to use mechanical devices to cool rooms that may be overheated by low efficiency lighting fittings and appliances. Achieving good day lighting to minimize energy consumption will require designing of the building opening and glazing for a correct balance between the heat gain and loss that may result from the transmission of thermal radiation in and out of the building and the light entering into the building. Careful considerations are therefore required in maximizing natural lighting through good orientation and geometry of spaces as well as location, form and opening dimensions in buildings.

The active energy lighting in buildings usually refers to as artificial lighting which is as a result of bad designs. Many researchers have carried out studies in this respect for energy efficiency. Haas (1997), considering energy efficiency indicators in residential sector, identifies lighting and appliances as fourth in the use of energy consumption in residential building sector. He further identified dwelling areas as an important explanatory variable for lighting, despite highly efficient Compact Fluorescence Lamp (CFLs) as a better indicator for measuring the intensity of energy consumption. This is simply an application of the product of the usage, efficiency and service level. The importance and application of artificial lighting in contributing to the increase in energy consumption is further stressed in Lam *et al.* (2003), study which revealed that lighting accounts for 20-35% of the total energy consumption in tropical buildings. The study concludes that for purposes of energy efficiency, the use of free natural lighting (day lighting) as a source to provide sufficient illumination level should be encouraged between the hours of 8.30am - 5.00pm (see Figure 2.11), when solar intensity is able to provide sufficient daylight luminance of about 100 LUX. Zafer and Arif (2004), study estimating the energy and energy utilization efficiency for residential and commercial sector in Turkey energy consumption is noted that electrical energy use for lighting range first to other uses. This further corroborates other views on the importance of artificial lighting in energy consumption.

However, according to a study carried out by World Business Council for Sustainable Development (WBSCD) (2007), on the indicators of energy efficiency, lightning is found to consume about 18% of energy use in buildings. This improvement may not be unconnected with development of high energy efficient lighting fittings. A further study by Li and Tsang (2008) on facade engineering design to aid artificial lighting improvement showed that good building facade design utilizing day lighting can reduce over 25% of total electric lighting energy consumption. While recommending that attention should be given to issues of glare and solar heat gain in building, Yang *et al*; (2010)'s study on major factors on energy consumption in Chinese residential building identifies difference in lifestyle as one of the key factors that affects lighting energy consumption. It was also noted in the study that the luminosity of a Lamp is measured by the size of a room, as key determinant to the service level as a service demand indicator for lighting consumption.

Further study by Rahamatabadi and Tomshimalani (2011), on architectural energy efficiency concluded that utilized energy in building by electrical appliances and equipment including lighting consumed about 35% of energy consumption. This is in reference to IEA and OCOED countries indices. Yao *et al*;.(2012), in an holistic method to assess energy efficiency, categorises lighting as a weighted indicator for energy efficiency indicators for residential building facilities assessment, as ranking second to Air conditioning in energy consumption rate. This agrees with the works of Yang *et al* (2010), which confirmed the importance of lighting issue on energy efficiency towards designing of residential buildings.

However, it is pertinent to note that Eti-osa *et al*; (2009), report on energy efficiency survey in six major cities in Nigeria and noted that major challenges had been experienced in formulating a viable energy policy for the country. This has undermined the importance and gain of energy efficiency on environment and economic growth. The report also noted that a lot of energy is wasted in Nigeria, because both private and public households, offices and industries, use old and inefficient equipment and production process. Other findings include the dominant use of incandescent light bulbs, while people living in low voltage supply area use between 100w and 200w in order to get a good level of luminance for tasks.

The tendency to use artificial lighting for advert purposes for goods and switching them on during the day and night was also identified as one of the areas of inefficient energy consumption. Similarly, the outdoor lighting during the day is a usual occurrence; despite the finding of experts that day lighting utilization is effective at the same period. According to available statistical data, as revealed in the 2006 national survey, more than 50% of regular households in Lagos use electricity as their main source of lighting fuel. This figure represents about 1,891,540 households, and may also be significant in considering energy consumption in the study area. At present only about 10,323,427 households in Nigeria use electricity for lighting purposes (federal bureau of statistic 2012). Lighting, therefore, constitutes an important factor in considering a design for energy efficiency in the residential building sector for the control of energy consumption.

2.2.3 VENTILATION ENERGY CONSUMPTION

Ventilation usually refers to the rate of air movement in and around buildings. In architectural design, it is used to drive effective cooling for the comfort of the occupant. This cooling could be achieved in building design through passive and active energy means.

Natural cooling in building is achieved by air movement through wind pressure differential and temperature gradient effect. The stack design effect can be put to effective use in order to release unwanted heat from a building via court yard or atrium. This does not involve any energy consumption in buildings. This creation of natural air movement phenomena gives rise to the intake of air from the building into the sun space, thereby leading to a cross ventilation for cooling. In other words, mechanical system driven or powered by electrical energy are sometimes used at homes in occupied spaces including heat generating spaces such as living room and kitchen.

The energy consumption of the mechanical systems employed for ventilation purposes could sometimes be enormous. The energy consumption of devices such as fans, and extractors can only be controlled by manufacturers of the products through their ratings for efficiency. These products of energy efficiency controls are absolutely unavailable in the Nigerian market. The effect of ventilation cooling in building is however determined by the thermal condition of the building and occupants responses to temperature ranges at the same time. This response varies from different climatic regions and is controlled by outdoor and indoor temperatures in and around buildings most of the time.

According to studies, Sawachi (1987) identifies the possibilities of reducing the use of air-conditioning by supplementing it with passive measure for enhancing thermal comfort. In this regard, he suggested the use of window opening and turning on of fans (adaptive measure), since fans are seldom use alone. Macarthney and Nicol, (2001) study, shows that more Adaptive Approach towards temperature control might be beneficial both in terms of energy consumption and in occupant’s comfort, especially during summer. It realized that thermal comfort in real life is more dynamic of the indoor temperature (momentary), while outside temperature obviously results in some energy saving.

Ventilated cooling, on the other hand could, be achieved through the opening elements in buildings, usually the windows. Various studies undertaken in this area revealed that, the level of success of ventilation depends on the rate of air movement, window glazing, window sizes, their position and orientation. Also of importance to occupants to achieve good ventilation cooling are the available control means. The building form, shape and orientation also play a significant role for its attainment.

Asimakopoulus and .Santamouris (2005), in their study conclude the shapes of the building can affect natural ventilation, since area of low and high pressure has an influence on it. However, further study by Stelios *et al*. (2012), observed that the buildings shape does not affect performance concerning natural ventilation. This is because air speed and air flow around studied model do not show any significant measure at the level of openings. However ventilation cooling is only applicable to naturally ventilated and mixed-mode buildings.

2.2.4 ENERGY CONSUMPTION INDICATORS

One of the most effective means of reducing building energy consumption is the assessment of building energy efficiency. However, this cannot be achieved without identifying those factors and indicators that encourage intensive energy consumption. This section identifies these indicators, as they may affect energy consumption in the residential buildings. Many researches have been carried out on the indicators of energy consumption.Adebamowo (2007), Olaonipekun (2002), Burbery (1997), and Lutzenhenzer (1988) identified dwelling characteristics such as orientation, shape and size, site location, use of buildings, design Layout and building envelope as important factors which influence energy consumption pattern. However continuous researches on this have led to different categorisation of factors with various identified indicators weighting. Yang *et al*. (2010) categorises the factors that influence energy consumption into five different areas viz:

1. **Building Design** with three indicators involving orientation, shape and outdoor environment of building.
2. **Building Envelope performance** with indicators including insulation, air tightness and shading.
3. **Building energy efficiency facilities** with indicators encompassing HAVC, lighting and water facilities.
4. **Building operation and Management**. Involving indicators as facilities operation, qualification and energy efficiency consumption statistic awareness
5. **Comfort and Health** with indicators capturing indoor thermal environment, lighting, acoustic and indoor air quality.

Yang *et, al.* (2010) and Yao et, al. (2009) list of identified indicators agree and cover such as have been proposed by Cong *et al*.207 Wang, 2006, and Lin *et, al*. 2006. These were derived from four rules that include: Feasibilities, Completeness, Effectiveness and Multi-attribute decision making rules.

A critical assessment of these indicators reflects a purely technical submission as the human behavioural control is conspicuously absent. However, the need for energy consumption indicators in the residential sector is further strengthened through understanding the components of change in household energy use, which provide the key to strategic planning for future energy use, This, according to Hass's, (2009) study, is therefore more important to show which aspect of housing population, dwellings, equipment stock and other structural parameters influence energy consumption by end use. The study however identifies structure, climatic demography behaviour, technical and economic factors as some of the driving parameters for energy consumption. Understanding these parameters easily lead us to variables explaining household energy demand such as household population, energy prices, individual attitude, life style with regard to time spent at home or work. The dwelling area in respect of structure, efficiency in terms of technology of home equipment, while climate specifically signify differences in heating and cooling degree days as policy address issues of taxes and demand side management.

In aggregate terms, this study can therefore identify and categorise the energy consumption indicators into three factorial areas covering: Building Design factor, Environmental factors And Human behavioural factor

Categories	**Indicators**
Building Design Factor	Building Orientation, Building Form, Shape, Size of Building, Building Openings shading and Roof, Material for Construction.
Environmental Factors	Indoor thermal humid environment. Outdoor thermal temperature environment, Indoor Lighting and Indoor air quality.
Human Factors	Occupancy Rate, Activities types, Control access, Comfort behaviour.

It is worth noting that building modes is not listed, as factors of design factors, which researches have been found, to a great extent, affect energy consumption. This factor determines the consumption on the basis of building dependent of passive or active means of energy use in building could therefore be included for consideration.

2.3 ENVIRONMENTAL FACTORS AND ENERGY CONSUMPTION

This section examines the impact of environmental factors on energy consumption and their relationship with residential household’s internal condition in the built environment, emphasizing their effect on occupant’s behavioural actions.

The built environment is formed by the buildings and other objects constructed in the natural environment. According to Mason and Hughes, (2001), modern buildings have various purposes, but all provides an internal environment different from the external. At the same time, a climate of the natural environment, the shelter of the built environment and human activities are linked by physical process and an outline of independent relationship. It is therefore the environmental factors which drive this relationship that explain energy demand. This factors is referred to as environmental variables. This section therefore identifies and examines their influence on energy consumption.

However, a building's first main function is to protect occupants against harsh outdoor climate and provide a comfortable and healthy environment for them at the same time. In providing for this comfortable and healthy environment some factors have been identified through research that determines it. These factors are referred to as THERMAL COMFORT determinants. The technical aspects of these factors are responsible for occupant's behavioural action which determines the energy consumption of households. This has been identified as environmental variables in energy study. They include: **Air Temperature**, **Mean radiant Temperature (MRT)**, **Air movement (Velocity)**, **Relative Humidity (RH)**
However for the purpose of energy study, the environmental variables directly responsible for energy consumption in most researches have been emphasized. They are:

(1) INDOOR and OUTDOOR TEMPERATURE

(2) INDOOR and OUTDOOR RELATIVE HUMIDITY

This is founded on the premised that the Air and Mean Radiant Temperature determine the indoor temperature hence the thermal comfort temperature that drives the energy consumption.

2.3.1 AIR TEMPERATURE (DBT)

The air temperature of an internal space (room) in a building varies from spot to spot. Humphrey (1973) found out that the temperature measured near ceiling level in a school classroom with warm air convector heating can be as much as 10^0k higher than the temperature experienced by the children on the floor. In this study area, daily maximum temperature is usually between 29^0c and 31^0c which usually occurs during the day in the hottest month of February and March. However measurements for both outdoor and indoor DBT, the diurnal range was between 1^0c-3^0c which is significant to energy consumption.

However Adebamowo's (2007) study in Lagos found out that occupants still express satisfaction with 27^0c indoor temperature in most residential buildings. The implication of this to energy consumption is that occupant's available control of operating fan or air conditioner could be made depending on the building mode of the household. Lagos minimum temperature usually occurring between the evening and the early morning, and the day temperature is usually high. This usually has a significant effect on energy consumption, as the city is noted for hybrid of day activities. Going by the indication of the IPCC report, the surface temperature for Lagos increased by about 1^0c in the period between 1970 and 2004, and prediction that the last decade of the century (2090-2099), that the temperature would increase by 3^0c03.5^0c. The effect on energy consumption is better imagined, as suggested by Nicol *et, al*. (2005) in the three reasons why thermal comfort is important. The temperature which people try to achieve in their house is an important factor which determines the amount of energy it will use. The influence of the air temperature is therefore such that it determines the indoor comfort temperature of the internal building environment, and consequently the indoor air quality in a naturally ventilated building. This is also true for the cooling temperatures in mixed mode and mechanical ventilated buildings.

2.3.2 RELATIVE HUMIDITY

The changes in the amount of precipitation and variation in humidity (both outdoor and indoor), to a great extent, affect both consumption and production of energy. This study demonstrates that significant impact on energy demand is due to higher indoor temperature and humidity which could consequently raise demand for air condition during the day in the study area. Lagos has a warm humid climate with humidity reaching over 80% in the morning, but rarely dropping below 65% in the afternoon. This is the major cause of discomfort in households. This dehumification process has strengthened the choice of air conditioning in Lagos which has become highly necessary for indoor environment. Sangowawa and Adebamowo's (2010), study makes relative humidity significant to energy consumption in the study area. The impact, according to most researches, is responsible for up to 60% of energy consumption in tropical buildings. High values of RH were generally observed in most households where measurement were taken, the study recorded indoor RH mean value of 64.7% as the outdoor mean RH value stood at 66.7% respectively, during the period of field measurement in the study area.

2.3.3 AIR VELOCITY

This is the rate of air exchange in buildings which aids occupant's ventilation comfort. It is usually achieved by air movement through buildings, which can be induced by stack effect, wind pressure differential, or mechanical means such as fans, evaporative coolers and air conditioners. External features which include, numbers, size and position of openings components are some of the factors that affect air flow through buildings, hence air velocity. Air velocity which is responsible for air flow around building is therefore determined by the shape, height, orientation and planning of building, Givoni, (1976).

Energy consumption in relationship to air velocity can be seen from both passive and active consumption. The passive energy is determined by the wind pressure differential which is responsible for air flow around buildings and is driven nature. This is majorly relied on in natural ventilation building mode and aided by building opening characteristics. The active energy consumption is usually depended on in both mixed and mechanical mode buildings, to aid indoor climatic condition for ventilation and cooling. This is through electrical appliances such as fans and air conditioners in the study area. The warm humid climate of the study area makes the use of mechanical aids employable to aid air movement due to the high rate of humidity presence in the air. However, a recommended standard of wind velocity in the city centre by IHVE guide is 3m/s which are rarely attainable, thereby necessitating the use of these electrical appliances for occupants cooling comfort.

2.4 OCCUPANTS' BEHAVIOURAL ACTIONS AND ENERGY CONSUMPTION

Energy consumption in buildings and residential buildings uses a greater percentage of energy end use in the attainment of indoor comfort, specifically thermal comfort. Research findings show that in most tropical buildings, air conditioning system accounts for 30%-60% of energy use for cooling and dehumification purposes (Yao *et, al* 2012, Rahadmatabadi 2011 and Mornal*et.al* 2008).This is essentially used in maintaining good thermal environment through the use of various available control mechanisms, as provided by design for occupants.

In view of the above, this section explores the impact of thermal comfort attainment on energy consumption in the study area. Thermal comfort is a psychological phenomenon defined by the American Society of Heating, Refrigeration and Air conditioning Engineers (ASHRAE) as "that state of mind which expresses satisfaction with thermal environment". Most researchers identified and agreed that **air temperature**, **relative humidity**, **solar radiation**, **air movement**, **clothing**, **metabolic activity** comprise the six factors that determine thermal comfort. While the first four factors are identified as being climatic, the other two can be classified as personal. It is vital to note that both have an impact on the amount of energy consumption in residential building. Adebamowo's (2007) study on this in Lagos found that occupant is comfortable in the range of 27^0c indoor temperature and 70% relative humidity. This is however slightly higher than (ASHRAE 55-2004) recommendation, which makes adaptation of occupants very vital to both thermal comfort attainment and energy consumption implications.

Many researches on occupants' behaviours show interesting finding. Dick *et al*, (1951) for instance, found out that United Kingdom field study demonstrated that there is a correlation between the ratio of open window and outer temperature. While extensive studies on the relationships between occupants' adaptive behaviours and thermal environment, with respect to regions and survey attributes as well as types of adaptive behaviours are found to include: opening windows, turning fans and air condition on and off and changing clothing, (Raja *et al*, 2000, Nicol *et al*, 2004, Rijal *et al*, 2007a, 2007b, Carli *et al*, 2007, Yun *et al*, 2007, Herhel *et al*, 2008 and Robinson *et al*, (2008). It is however noted that occupants of dwelling houses have greater freedom to control their environment than occupants of offices.

As Nicol *et al* (2004) pointed out the necessity of examining a combination of behaviours, stating that the use of one control may change the use of another. This could, to a greater extent, determine the intensity of energy consumption of the households. However, Sawachi (1987) on the possibility of reducing the use of AC by supplementing it with passive measures for enhancing thermal comfort found out that the methods will be limited to when temperature exceeds 30^0c in temperate region. This inversely implies its limitation to adaptive temperature not exceeding 27^0c in the study area.

Adebamowo (2007) and Takashi *et al* (2008) observe that in all cases, occupants' behaviour, with respect to opening/closing windows, turning fans and AC on and off are significantly described by the indoor and outdoor temperatures, than other variables. The study therefore concludes that passive behaviours by occupants such as opening windows and using fans reduce temperature at which AC was switched on for temperatures as from 25^0c to 30^0c.They however, cautioned that it had little effect in the reduction of the temperature at which AC was switched on in high temperate environment, such as the study area.

Rijal *et al* (2008), deducing reasons for the use of building control, highlighted the tendency for people to open windows and use fans more often, if they would like to feel cooler and to use heating more often if they would like to feel warmer. Exploring the interaction between window opening and other control found out that the likelihood of window opening is higher when the fans are not switched on for all building types. While the proportion of window opening is low when the air-conditioning is running (AC on), except in Europe, as the proportion of window is less when heating is on. The study therefore concludes that window opening behaviour is consistent with energy saving. This is with the exception of window opening in some buildings when the cooling is on.

Occupants' adaptation strategy to thermal comfort on the other hand, necessitates their dependants on the available design social and physical characteristics of the building opportunity to attenuate their thermal environment. This ability of occupants to change their behavioural attitude also goes a long way to determine the amount of energy consumption of households. This is however premised on the building design ventilation mode of the household. Natural ventilated household's mode provides control tendency to window opening, which contributes to reduce energy and passive in nature. This is however applicable when the weather outside is not very hot. This accords with (Kolokotrom *et,al* 1996) assertion that naturally ventilated buildings consume less than half as much as energy those with air conditioning. Reliance on the provision of mechanical systems to alleviate the more extreme condition is however energy intensive. Again, the choice of air conditioning has also been strengthened by the problem of dust-laden atmosphere of Lagos and the prevalent noise and vehicular pollution in high density communities and commercial capital of Nigeria (Sangowawa, Adebamowo 2010). This makes mechanical ventilation and air conditioning a necessity for occupants thermal comfort satisfaction in the study area. This does not encourage energy conservation and efficiency. While changes in the amount of precipitation and variation in humidity, wind pattern and number of sunning days per year could also affect energy consumption and production, understanding the tropical bioclimatic architectural concept could be the first step to optimizing energy consumption in the warm humid climate zone of Lagos. This is further confirmed in Steven *et, al*.(2007) on ASHRAE 55-2004 adaptive method examination and review which identify limitation on its application to mix-mode design, though coupled with unfamiliar calculation and compliance. The mix-mode is a hybrid approach to space conditioning that uses a combination of natural ventilation from openable windows (either manually or automatically controlled) and mechanical system that provides air distribution and some form of cooling (air conditioning, radiant cooling etc.). This is with the realization that by utilizing mechanical cooling only when and where it is necessary to supplement the natural ventilation, a well-designed mixed-mode building offers the potential to improve the indoor environment air quality, while minimizing the significant energy consumption.

2.5 ENERGY CONSUMPTION CONTROL IN BUILDINGS

Until recently, energy research in architecture has focused on individual building component and characteristics, rather than the whole building system for optimal design. It is therefore necessary for designers to understand the building as a dynamic energy system. This is explained in the interrelationship between passive and active energy system.

According to Busch (1994), in passive and low energy cooling of building, the physical processes have been characterised and understood since the last century. The recent concern is on the identification of how these processes interact to affect energy consumption pattern for the building as a whole. The role of architecture in energy consumption will therefore include and not limited to the following:

(1) Energy consumption process and Interactions patterns

(2) Identification of sources of Energy for consumption

(3) Energy Consumption Optimization

(4) Energy Conservation and Efficiency

Previous studies made by Givoni, Harolt, Bruce, Arthur, Peter (2001) and Robert agreed that buildings use energy for heating, cooling, lighting, ventilation, cooking and for operating equipment and appliances for the comfort occupants of building. As it relates to the warm humid climate of Lagos, the concern will be on cooling, lighting and ventilation for a sustainable living condition.

However, pattern of energy use is strongly influenced by architectural designs and the activities that occur within several building types, the energy cost and economics. Added to this is the issue of building materials used for construction and consideration for environmental architectural design factors. The prevailing climate change scenario as they affects energy usage is an important consideration as well. Great architects and their works in the past greatly rely on passive energy and as such were deeply influenced by climatic principles. Markus and Moris (1980), Adebamowo's (2007) studies affirmed that before necessary measurements and theoretical method were developed, the application of climatic knowledge to building designs was based on the architect's knowledge in classical theories of elements, personal observation and, to some extent, the living vernacular tradition which they observed. Such were reflected in the works of great designers like Vitruvius, Alberti, Paladio, Frank Llyod Wright, Le Corbusier, Gropius and host of others. The departure from this knowledge base caused the energy crisis in the late 70s which witnessed climate change scenario and global warming effect. This, alongside the works of scholars such as of Peter (2001), makes sustainable (low energy) designs a serious issue of concern in the built environment. The main aim of low energy designs is to maximise comfort for building occupants, while minimising and ultimately eliminating fossil based energy use. Movement for this innovation identified six performance indicators as a condition for the attainment of a sustainable design. While three are design based, three are mainly infrastructural in nature. This research is however concerned with the Design based indicators such as Operational Energy, Embodied Energy and Biodiversity.

Operational Energy: Energy consumed during the in-use phase of a building life. In relation to sustainable construction, the operational energy use of a building is its biggest environmental impact. Therefore, reducing the operational energy use and increasing durability should be the prime concerns of Architect who wish to design and build "green buildings"

Embodied Energy: This refers to the energy consumed by the processes associated with the production of a building from the mining and processing of natural resources to manufacturing, transportation and product delivery.

Biodiversity: This is the variety of different types of life found on earth and the variations within species. It is a measure of the variety of organism present in different ecosystem: Biodiversity conservation is about saving life on earth and keeping the natural ecosystems functioning and healthy.

As it relates to energy, it is the source of energy with particular relevance to carbon emission and the impact on ecosystem and environmental impact, having direct relevance to global warming effect and occupants' health and general condition.

The environmental consideration in building designs is therefore primarily aimed at maximising passive system so as to reduce reliance on active system that uses energy. This makes operational and embodied energy a great concern to designers. Both determine, to a great extent, the active energy consumption of any building. However, of concern is the fact that, the integrated planning needed for most of the passive cooling and natural ventilation concept is rarely realised at the building design stage. This is because of the lateness in the consideration of energy issue, such as detailed building technology at a stage when all decisions concerning building characteristics had already been taken.

But for Pears (1998), the issue is hinged on the sustained growth in the household income over the last couple of decades, with falling real prices of air conditioners equipment and electricity tariff. Extending this view, Pareto (2003) noted that energy used in air conditioned building is about twice that of naturally ventilated buildings. This accord with previous views noted by researchers. This aggregated view therefore suggests a hybrid design situation for possible conservation and efficient energy consumption in form of a mixed mode buildings, most especially in a warm and humid climatic situation of Lagos. To this end, bioclimatic tropical architecture needs to be generally encouraged and adopted in the residential built environment.

Some research suggestions have also been given. For instance, Ashok and Ruchi (2007), proposed that the first level of energy economy in building is an informed assessment of needs and standard for climatic zone of concentrated urban development. Also, there is the suggestion that traditional passive strategy for climatic comfort display new exigencies of city living. It is also suggested that new material and technology of construction are responsible for poor thermal performance of most construction. This, as a consequence, results in poor energy use in buildings. It could be understood from most studies in energy efficiency, that our traditional passive strategies could not be completely abandoned for new construction materials. At the same time, the peculiarity of our climatic zone should be well understood and applied to design so as to achieve optimal energy use through good thermal building performance and occupant’s thermal comfort satisfaction.

Jacob (2007) also identified new trends in architectural designs, of a better insulated and more air tight envelopes, resulting in modern buildings being less able to lose heat naturally. What results is a more reliance on effective ventilation for passive cooling. The study justified this through the social trend of occupants’ reluctance to leave window open, particularly in urban areas, because of noise, air quality (pollution) and security issue. Also is the fact that modern homes have more number of electrical appliances and lighting fittings, which further raise internal heating. The result is a high energy use.

In summary, the dynamic interrelationship of energy and architecture in the built environment in recent time is the resultant sustainable issue of energy optimization and efficiency issues in design towards behaviour of occupant and the nature of specific climate differ on basis of regional, national and international locations.

2.5.1 IDENTIFICATION OF ENERGY CONSUMPTION SOURCES

Nigeria’s available statistical data between 2005 to 2009 in terms of electrical facilities and distribution show a great percentage increase within the years. While dependence of household on public electricity grew by 7.7%, mixed public/private use only grew by 3.3%, as private dependence account for an increase of 0.4% during this same period. Other sources sharply decrease by 10.6% distribution. This aligns with IEA finding, as revealed by General households survey. See Table 2.3

During this same period, electricity supply by power holding company grew steadily from 47.3% in 2007 to as high as 82.2% in 2010. Lagos state share from this only accounted for 67.3% to 67.9%, showing an increase of 0.6%, only within this period.

The patterns of sectorial energy use also vary significantly between OECD and non- OECD countries, as the final energy mix is also quite different. See Fig 2.12

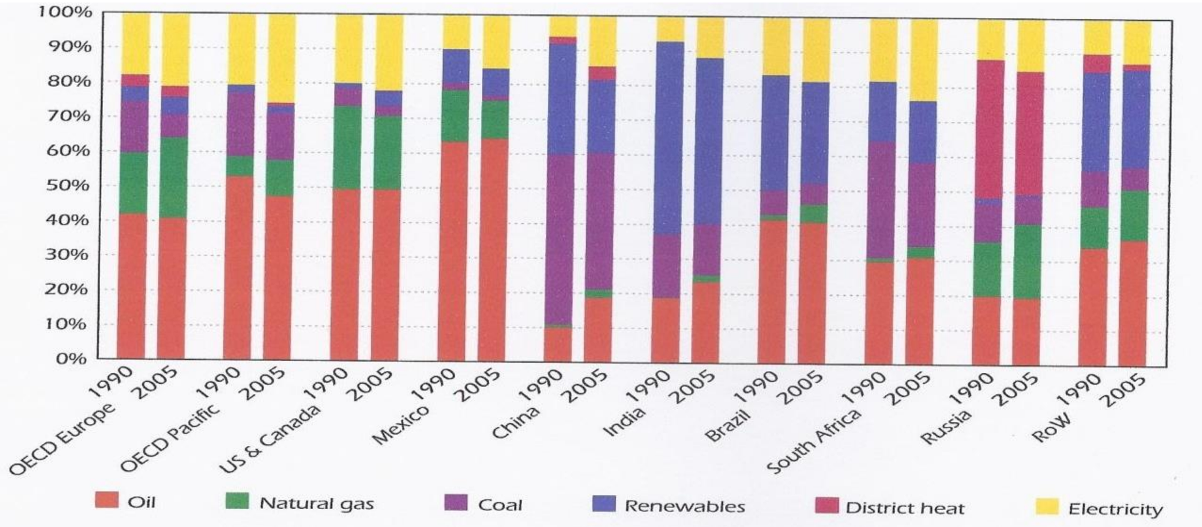


FIG.2.12 Total Final Energy Consumption by Energy Commodity

(Source: IEA, 2007c; IEA,2007d; IEA estimate.)

Note: Excludes fuel use in electricity and heat production.

The oil products consumption in non-OECD countries, as reported, on average, accounted for 28% of the total energy use as at 2005. It is worthy of note that these countries not only use it for transport, but are important fuel used in industry and household for electricity supply. Electricity, however, represents 14% of final energy use in non-OECD countries. Today, this figure will have been enormous, due to economic and massive infrastructural developments that are being undertaken by governments.

Table 2.3: Energy Consumption 2006-2010

Type	Weight	2006	2007*	2008*	2009*	2010**
Coal	0.13	8,050.50	22,549.90	31,799.40	33,533.40	37,745.30
% Share	0.13	0.00	0.10	0.20	0.20	0.20
Hydro – Power	0.93	2,965,770.70	3,113,567.20	3,669,824.50	3,675,254.50	3,582,840.00
% Share	0.93	17.00	19.60	18.70	20.40	20.20
Natural Gas	0.04	1,310,102.50	1,740,5355.10	1,854,259.70	1,066,913.70	1,691,261.50
% Share	0.04	7.50	11.00	9.40	5.90	9.60
Petroleum Product *	98.90	13,137,540.50	10,991,393.80	14,098,510.60	13,241,582.70	12,393,471.60
% Share	98.90	75.40	69.30	71.70	73.50	70.00
Total	100.00	17,421,464.20	15,868,046.00	19,654,394.20	18,017,284.30	17,705,318.40
% Share	100.00	100.00	100.00	100.00	100.00	100.00
Index of Energy Consumption (1990=100)	-	170.00	181.90	205.00	198.70	192.40

(Source: National Bureau of Statistics, Annual Abstract of Statistics 2012.)

Energy consumption between 2006 to 2010 in Nigeria, according to available statistics, shows that the mix energy uses are shared among coal, hydro-power, Natural Gas and petroleum product.(NBSAAS, 2012) Table 2.3 above indicates that oil has the largest share, followed by hydro-power, natural gas, with coal occupying the bottom of the table. The implication simply further confirms IEA analysis, in term of Co_2 emission in none OECD countries which requires the urgent attention of various governments.

It is also clear that energy consumption from main electricity supply falls short of about 5,000MW. This may have a serious effect on required energy among the households studied.

A faster growth in CO_2 emissions of (+39%) in 2005 reported in non- OECD countries than OECD countries, (+15%) final energy use implies that a serious attention is required as up to date data for policies on electricity generation and consumption increase the carbon intensity of energy use FIG. 2.13.

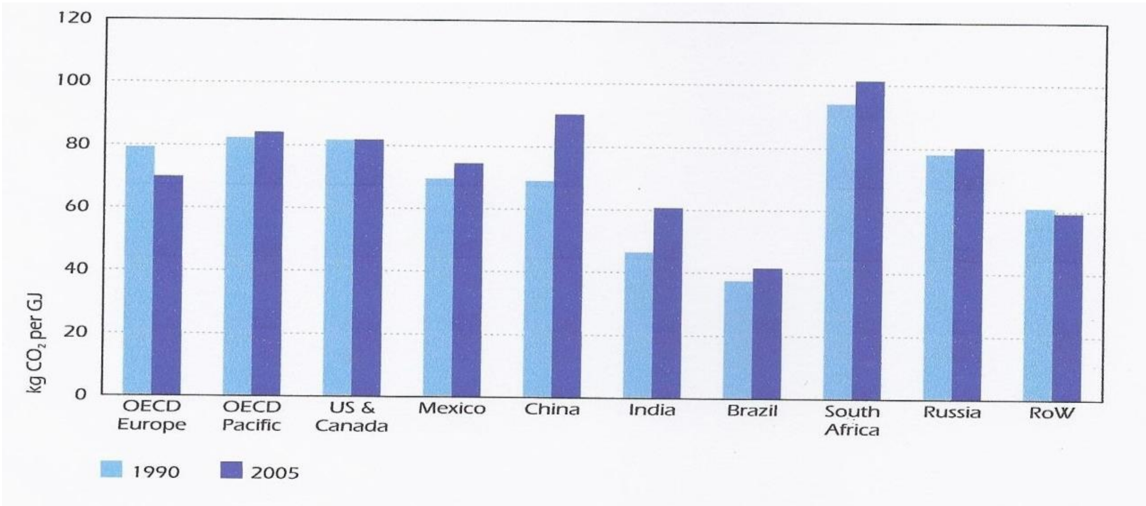


FIG.2.13 Carbon Intensity of the Final Energy Mix

(Source: IEA, 2007c; IEA,2007d; IEA 2007e; IEA estimate).

2.5.2 ELECTRICITYCONSUMPTION AND COMFORT

Electricity production is said to be responsible for 32% of total global fossil fuel use in 2005 which is about 41% of total energy related CO_2 emission, also accounting for 132EJ. To however combat climate change and improve energy security, it is important to improve the efficiency with which electricity is produced. This will also help in reducing the world's dependence on fossils fuel consumption for electricity production.

Fossils fuels are said to be the source of 66% of global public electricity production, as the OECD countries share is reported to be slightly lower at 61%, while developing and transition countries average is 72% as at 2005. South Africa (94%) was ranked among the high share of fossil fuel use for public electricity production. Nigeria's contribution today is better imagined, if her aiming at 2020 is to be a reality. The electricity generation in Nigeria has consistently relied on two major sources: hydro and thermal generation. From these sources, the installed generation capacity between 2007and 2011 stood at 7,9599MW to 8,902.0MW which has never been reported supplied at any point in time (See Table2.4 below). Furthermore, detailed energy generation sources and quantities are as reflected in Table 2.5 with references to Hydro and Thermal sources, while Table 2.6 clarified percentages electricity type distribution of Households. The national outlook shows that public percentages only progressively increase, as other sources decrease.

Table 2.4 : Installed Generation Capacity 2007-2011

			MW
Year	Thermal	Hydro	Total
2007	6,021.5	1,938.4	7,959.9
2008	6,531.1	1,938.4	8,469.5
2009	6,763.9	1,930.0	8,693.85
2010	6,487.0	1,930.0	8,417.0
2011	6,972.0	1,930.0	8,902.0

(Source: National Bureau of Statistics, Annual Abstract of Statistics 2012.)

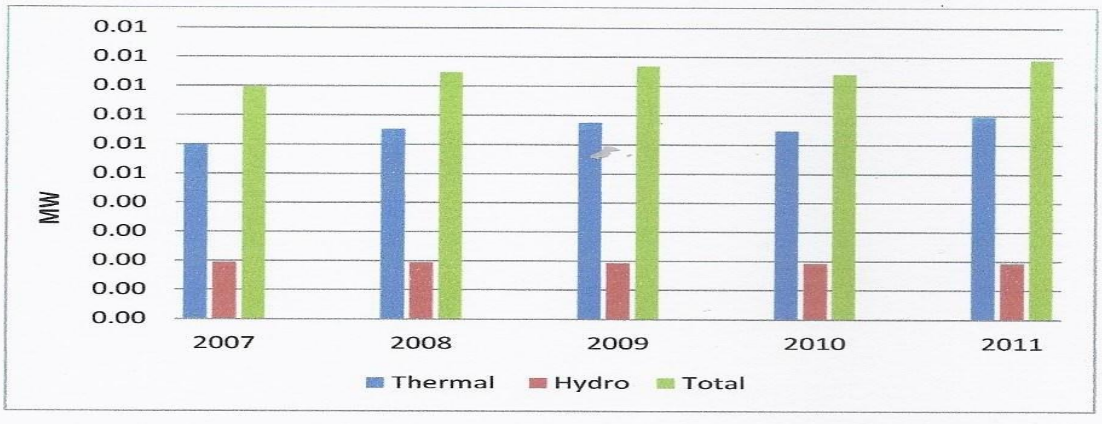


FIG.2.14 Installed Generation Capacity 2007-2011

(Source: National Bureau of Statistics, Annual Abstract of Statistics 2012.)

Table 2.5 : Electricity Generation, 2007-2011

Power Station	2007	2008	2009	2010	2011
					MWH
HYDRO	**7,776,409.70**	**7,443,340.00**	**7,265,140.00**	**7,415,848.00**	**6,710,274.65**
Kainji	2,816,749.70	2,794,976.00	2,505,663.00	2,300,991.00	1,769,044.75
Jebba	2,728,899.00	2,089,460.00	2,676,860.00	2,693,741.00	2,567,236.90
Shiroro	2,230,761.00	4,528,451.09	2,082,617.00	2,421,116.00	2,373,993.0
THERMAL	**15,410,133.22**	**17,216204.78**	**21,123,384.18**	**25,484,394.28**	**17,406,924.15**
Ijora	-	-	-	-	
Calabar	-	-	-	-	
Lagos (Egbin)	3,636,680.32	1,846,704.40	3,383,990.30	5,385,475.96	6,752,677.73
Sapele	490,790.00	728,977.00	121,269.00	493,254.65	761,632.82
Delta	2,696,718.60	1,510,988.00	1,591,572.70	1,957,869.10	1,492,559.95
Afam	1,274,102.70	2,794,976.00	151,048.00	96,156.80	416,244.50
Omotosho	146,800.91	300,209.60	383,265.50	144,212.00	373,526.80
Olorunsogo	0.00	418,545.88	103,581.00	270,295.90	1,162,818.63
Geregu	1,193,552.88	995,874.58	652,603.19	776,765.06	1,698,438.40
AES	1,675,496.28	491,324.90	1,681,451.43	1,538,650.72	1,557,066.58
Okpai	3,294,207.00	2,708,670.00	3,079,384.00	3,232,402.00	2,986,405.00
Ibom	-	-	3,204.00	283,452.22	316,537.65
Trans Amadi	-	-	-	75,220.16	-
Ajaokuta	572,517.00	30,344.00	-	-	-
Omoku	429,267.53	297,580.26	422,355.13	194,932.16	157,408.05
Afam VI	-	42,960.00	2,129,058.73	2,763,336.17	139,017.31
Inpendent Power Plant (IPP)	5,971,487.81	5,025,638.94	7,315,453.11	8,255,624.67	-
NESCO	126,788.42	23,390.82	105,148.09	16,746.71	8,418.99
Total	29,284,819.15	26,629,098.15	28,388,524.18	32,900,242.28	21,480,066.26

(Source: National Bureau of Statistics, Annual Abstract of Statistics 2012.)

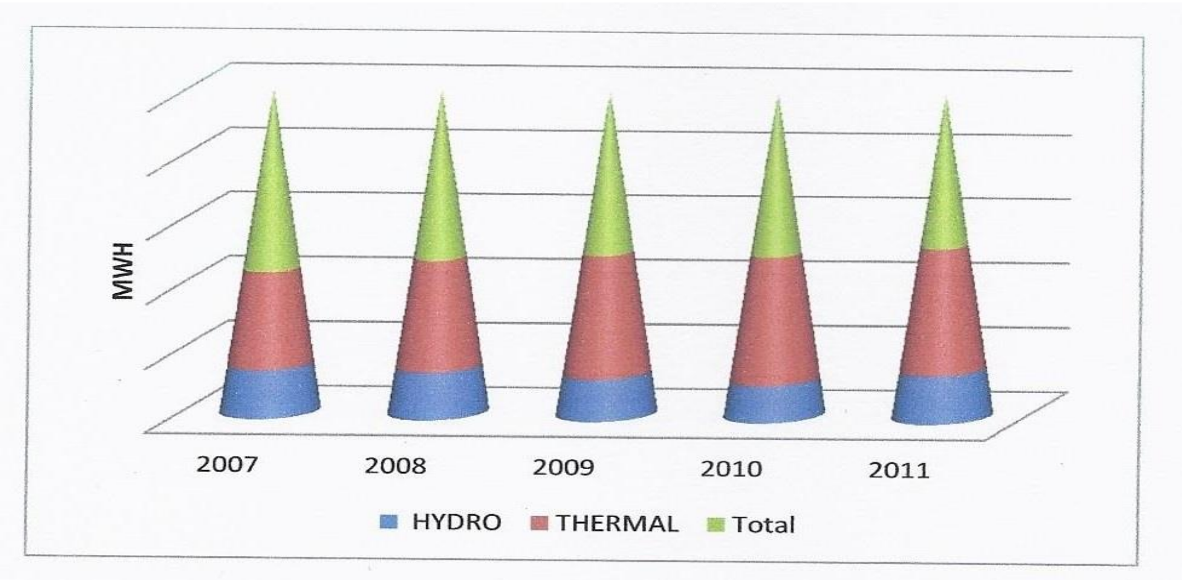


FIG.2.15 Electricity Generation, 2007-2011

(Source: National Bureau of Statistics, Annual Abstract of Statistics 2012.)

Table 2.6 : Percentage Distribution of HouseHold by Type of Electricity Facilities, 2005-2009

Percent

Type of Electricity	2005	2006	2007	2008	2009
Public Only	43.6	39.6	47.3	41.3	51.3
Public/Private	4.3	2.15	5.8	7.4	7.6
Private Only	3.4	1.8	2.7	3.2	3.0
Others	48.7	56.6	44.2	48.0	38.1
Total	100.0	100.0	100.0	100.0	100.0

(Source: National Bureau of Statistics, Annual Abstract of Statistics 2012.)

Lagos residential neighbourhood has access to both public and private sources of energy for households' consumption. This is as reflected in Table 2.7 below. According to Lagos State Bureau of Statistic (2010), households' energy consumption from Power Holding Company is about 97.7%. Likewise 61.8% of households' energy consumption is from generator powered by fossil fuel due to power supply shortages. Solar energy sources represent only 0.3%, just as inverter source only accounts for 1.0% of energy consumption among households.

This represents only 1.3% consumption from clean energy sources, as carbon base energy consumption from generator source dominated the private alternative sources. The implication is that IPCC target of savings towards climate change scenario is far from been realised.

Table 2.7: Energy Use by Type

LOCAL GOVERNMENT	ENERGY USE BY TYPE			
	PHCN	**GENERATOR**	**SOLAR ENERGY**	**INVERTER**
Agege	98.0	52.7	1.5	1.0
Ajeromi-Ifelodun	98.0	54.8	0.4	1.0
Alimosho	99.4	58.8	0.1	2.0
Amuwo-Odofin	98.1	68.0		1.0
Apapa	96.7	49.1		
Badagry	93.0	58.4		
Epe	100.0	53.6		
Eti-Osa	97.9	72.4	1.4	5.0
Ibeju-Lekki	89.3	73.1		
Ifako-Ijaiye	96.7	63.7	0.5	2.0
Ikeja	97.3	63.2	0.6	3.0
Ikorodu	97.5	56.1		1.0
Kosofe	97.1	67.6		
Lagos Island	98.7	62.0		2.0
Lagos Mainland	98.0	66.7	0.6	
Mushin	98.9	61.5		2.0
Ojo	87.7	65.2	0.4	4.0
Oshodi/Isolo	97.9	56.7		1.0
Shomolu	98.9	67.6	0.2	2.0
Surulere	98.9	73.4	0.9	1.0
STATE INDICATOR	97.7	61.8	0.3	

Source: Lagos State Bureau of Statistics (2010)

2.5.3 ENERGY CONSUMPTION OPTIMIZATION

Optimization of energy consumption for thermal comfort, with respect to cooling, heating, lighting and operation of indoor appliances is the only compulsory role of architecture to achieve energy efficiency and conservation in the built environment. Moreover, in a climatic setting that is warm and humid, with lots of thermally insensitive buildings like Lagos, achieving this solely rests on the understanding of the effects of relationship between the four identified environmental factors on the building envelopes. Boredines *et.al* (2007) study points out that, buildings have to generally minimise energy consumption due to:

(1) Reduction of heat losses in winter time.

(2) Reduction of solar radiation in summer time

Therefore, low energy buildings are traditionally supposed to have maximally big thermal resistance of building envelope. Trodorovic (2004) is however of the opinion that building envelope is not needed from the point of energy efficiency, since it does not have to form the shield against heat or vapour flows. However, a scientifically known fact is that building energy performance simulation models allows for choosing of optimal characteristics of building envelopes on the basis of annual heat consumption. The model will help to optimise building energy performance even more on the condition that can change the properties of building envelope. Based on their study, Borodines *et al* (2008) identified properties of real building envelope as follows:

I. To minimise heat flow from the inside space to outside environment and vice versa (Temp. Control)

II. Minimise or completely prevent vapour transfer across the building structures. (Humidity control)

III. Minimise or prevent the influence of solar radiation on the inside space condition.(irradiation)

These are characterised by thermal resistance of building structure. Rr m^2 k/w resistance has no common parameter, but can be shown as solar radiation Rr.

Rr = QR – Q1

Where QR – heat flow from solar Radiation coming outside

Q1 – solar radiation heat flow that got outside.

Voss *et al* (2007), citied Voss's (2001) submission that small buildings will provide high visual and thermal comfort with low level of building technology and particularly without the need of mechanical cooling becomes very useful towards optimization of energy consumption. This means that small buildings will be more energy efficient and thermally comfortable with the absence of mechanical cooling. In a warm humid climate of Lagos, energy consumption could therefore be greatly optimised by exploring this possibility in design of residential buildings.

Vargar *et al* (2007) stated that orientation; shape, glaze area, thermal mass and type of facade are the main characteristic determinants of heating and cooling demand. It also includes the possibility of use of daylight, natural ventilation and many passive cooling technologies. With this, it is necessary to integrate energy and indoor climate aspect into the very beginning of the planning process as an efficacy of integrated design. This submission is holistic in nature as it considers most of the basic elements of energy efficiency, with respect to planning, design, building technology and material selections for buildings characterisation and optimal result.

Baruch (1994) in passive and low energy cooling of buildings, noted that solar energy can be utilised for cooling in solar- absorption cooling system but could be complex. He further identified the condition of passive cooling with appropriate architectural design concept of tropical bio-climatic architecture. Baruch however; pointed out that building gets heated up during the day; cools down during the night due to heat loss to outdoor air by convection and radiation loss by the sky (see Fig. 2.16). This process of cooling is further enhanced through treatment of micro-climate of the surroundings of the building, with regards to surface landscape element (particularly hard and soft scape) that discourage irradiation, while encouraging better air movement through tree shading.

Hence, this shows that natural cooling processes occur even without the provision of specialised passive cooling system. However, Baruch advised that application requires special details in designs and construction of various building components, including roof and other internal structural elements.

The understanding of this concept of tropical bio-climatic architecture could be the first step or tool attaining energy efficient building requirements in this climatic zone and consequently control consumption. Steven *et.al* (2007) on ASHRAE 55-2004 adaptive method examination and review identified limitations on its application to mix mode design, couple with unfamiliar calculation and compliance, making occupant control vital to architectural design.
They conclude that ASHRAE 55-2004 may drive a project team otherwise, inclined to adopt higher energy solutions. Therefore, standard is right for improvement to give scope to lower energy solution without compromising thermal comfort.
However, Steven *et al* (2007) cautioned that only when sufficient experience is gained, widening this application should reduce energy and environmental impact of space conditioning.

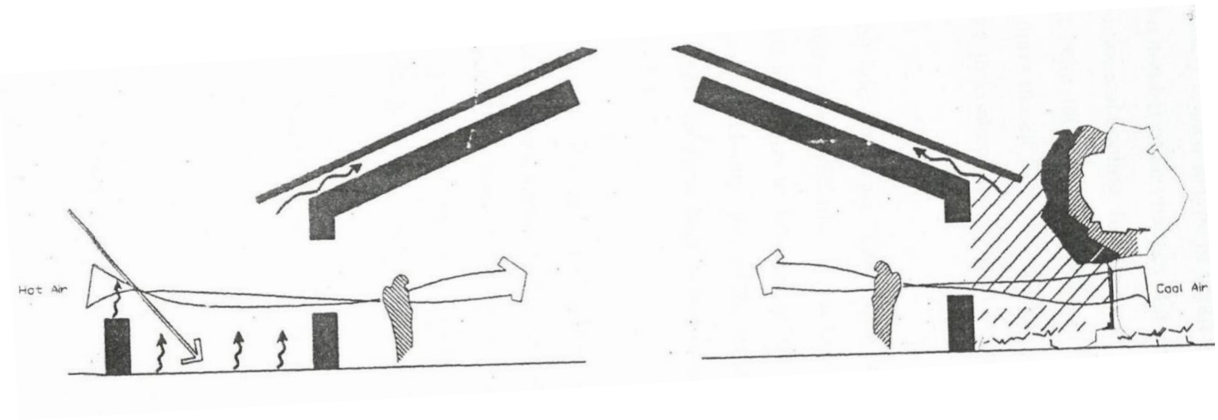


FIG. 2.16 Convective cooling is affected by the temperature of the external surfaces.

(Source: Ferreire (1986)

The study, therefore, concludes that the external shape of building can change its energy consumption, regardless of the materials and its usage in terms of material schedule and application choices.

Apte *et al's* (2003) study on openings also indicated that low level window typically save about 40% of building energy use attributable to windows in most U.S climates. They also stated that dynamic and ultra-efficient window with a U factor of about 0.57W/m^2K and a shading glass factor (SHGL) of 0.10-0.35 technology can use little or less energy than a home window. Again, the findings of Pleongeham *et al*. (2011), on the same study, show that dynamic windows with solar heat gain properties that vary with seasons, offer significant potentials in reducing peak demand in northern and central U.S climate. Similarly, low solar heat gain offers most potential in Southern U.S climate. Therefore, the application of these in the study area is dependent on the climatic similarities that may exist between central and southern US climates.

Also, in a life cycle assessment analysis, of advanced window system, Arasheh *et al* (2007), observed that an electro – chronic glazing can be suitable for cooling dominated climate with a potential of providing 55% energy savings. While Papaefthnion *et al* (2009), Singh and Gag (2009), in a detailed energy analysis study of buildings in India with ten different window systems, including single glazing and double low- e, absorbing film coated and reflective film coated glazing achieve, 17.72% energy savings in cooling dominated region and a 13.27% energy increases in heating dominated region. The study, therefore, recommended double low-e coated glazing for use to reduce building energy use in cold climate. Most of the findings in this study could be a guide for designers in making choice of window selection for the control of energy consumption in different climatic regions, as it may be applicable for use.

2.5.4 ENERGY CONSERVATION AND EFFICIENCY IN BUILDINGS

The role of architecture in energy efficiency and conservation in the built environment could therefore be directed towards, efficient building designed and construction. This is with the aim of producing high-energy-efficient buildings which optimised energy use, low cost of operation and producing less environmental impact than conventional building for sustainable existence.

Household energy conservation has been identified through researches to include the following: Sealing of Leak, Insulation, Ventilation Modes, Building Exterior Surroundings, Electrical Appliances and Equipment and Energy Monitoring.

These identified conservatory means largely depend on such factors as design, environmental and occupant behavioural actions. According to Borodimes *et al* (2008) and Trodorovic (2004) argument, sealing of leaks and insulations prevent or control and minimize temperature, humidity and irradiations. This will minimize heat flow, prevent vapour transfer and prevent solar radiation from inside and outside environment and vice-versa as may be required. This application however solely depend on regional climatic conditions, while heat consecrations is applicable in temperate climate, dissipation of heat is required in tropical climate of the study area. Sealing of leaks applies to opening in windows and doors, while insulation is applicable to walls and roofs.

Ventilation: Conservatory means addressed the building modes of households, researches identify different modes such as: Natural Ventilation System, Controlled Natural Ventilation System, Mechanical Ventilation, Balanced Ventilation System and Mixed Mode Ventilation

Three main means of ventilation have been categorically identified and classified as significant to energy consumption in the study area. They are: (1) Natural Ventilation (2) Mechanical Ventilation (3) Mixed Mode Ventilation System.

2.5.4.1 ELECTRICAL APPLIANCES AND EQUIPMENTS

This, according to the International Energy Agency (IEA), represents 34% of energy consumption of households in countries. This energy use is close to indoor comfort of 40-50% for cooling purposes. Their energy conservation has been made possible through manufacturer energy efficiency control by standard organisation. Within the study area, it can be made possible through importation control. Eti-Osa *et al*,(2009) study of six Nigerian cities, including Lagos attest to the dominant use of non-energy efficient appliances and equipment in homes, offices and industries.

2.5.4.2 ENERGY MONITORING

Energy conservation through monitoring is made possible only when there is a benchmark of energy consumption, through measurement of performance or compliance and rating systems for certification. When different climatic zones in Nigeria are benchmarked and rated for energy consumption in households through periodic audit process as required to be carried out periodically, energy monitoring by households and organisation can contribute immensely to energy conservation in the study area in particular and Nigeria in general.

With these identified means of energy conservation, process of designing, constructing and the renovation of a high-energy efficient building, will therefore move away from traditional design/build methods currently practised in Lagos. A new whole building approach can be suggested whereby architectural design is considered with its energy design to optimise energy consumption, currently referred to as integrated design in the built environment. If the mechanical and electrical systems energy consumption can be aggregated and optimised through product standard control for efficiency to help meet indoor space conditioning and lighting loads, it could lead to a definition of an architectural energy efficiency ratio factor definition as discussed below.

According to IEA energy consumption survey of nineteen Organisation Communities of European Development (OCOED) countries, energy consumption includes space and water heating, cooling, lighting and the use of appliances. Space heating is the most important energy use in residential building, accounting for over 50% of total energy use. However, current studies and findings on energy use are found to have differences on the basis of climatic, regional, national and international nature.

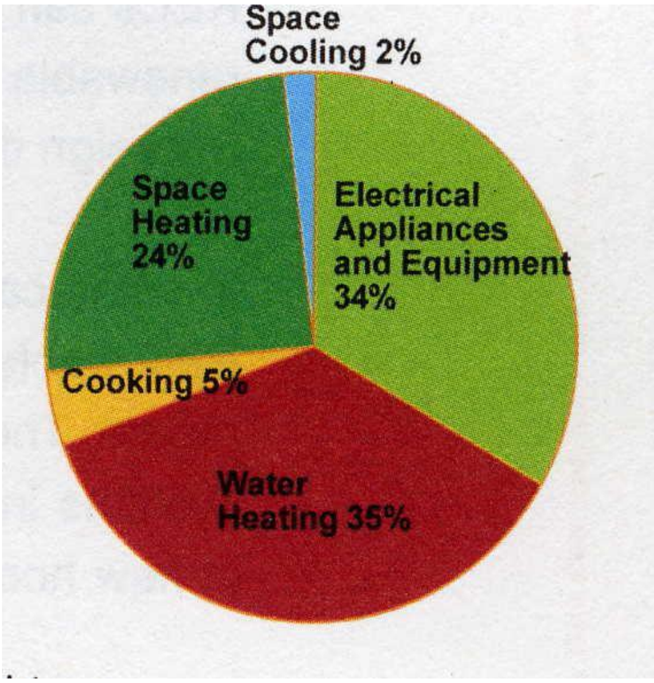


FIG. 2.17 Organization Energy Use Chart In IEA Countries

(Source: International Journal of Academic Research (Vol.3. No.2. March 2011, Part IV)

With an assumption that about 50% of this energy is usefully utilized and at least 50% of it is assumed dissipated. With Rahmatabadi *et al* (2011) study, it is possible to define a special coefficient for energy efficiency factor (AEEF) as:

$$AEEF = K\,(1-X')\,(1-Y')\,(1-Z')\,(1-K')$$

Where

X'= Space Heating Factor

Z'= Water Heating Factor

Y'= Space Cooling Factor

K'= Electrical Appliances and Equipment Factor

Hence, a special coefficient (architectural energy efficiency factor) as stated in the equation above could be established on the basis of available statistical data that may be collected from the field survey to be carried out. However, the study concluded that as this coefficient is close as possible to zero (0), buildings energy efficiency will be higher.

On the basis of climatic differences, tropical buildings are less susceptible to requirements of space heating, but require more of cooling for a comfortable control of internal environment. Therefore, energy consumption is predominantly based on cooling needs, lighting, ventilation, and electrical equipment and appliances. However, based on different available statistic in all organisations having activity in energy efficiency, it can be said that utilized energy in buildings mainly should be used in four segments such as listed below.

(1) X = Space Heating

(2) Y = Cooling

(3) Z = Water Heating

(4) K = Electrical Appliances and equipment

Therefore, substituting the energy use in their order of hierarchy of needs in tropical climate buildings in accordance with research findings, we have;

(1) X = Space Cooling

(2) Y = Lighting

(3) Z = Ventilation

(4) K = Electrical Appliances and equipment

With assumption of about 50% of this energy being utilized usefully and at least 50% of it is assured dissipated, the study can define a special coefficient (AEEF) as

X'= space cooling

Y'= lighting

Z'= ventilation

K'=Electrical Appliances and equipment

AEEF = K (1-X’) (1-Y’) (1-Z’) (1-K’).

Therefore, in line with Rahmatabadi’s (2011) submission, if this coefficient is as close to (O), possible energy efficiency will have higher level in building. An application of this to the current study in accordance with measured variables, architectural design efficiency can therefore be defined.

However, readjusting this for adoption in the study area could be made possible in accordance with the requirements of a warm climatic region. The major area of use will therefore be cooling, lighting, ventilation, equipment and cooking. Hence, energy use for space heating is replaceable with cooling, while lighting replaces cooling and water heating is substituted with ventilation. The water heating and cooling are merged together, while electrical appliances aid equipment are retained. On the basis of this, assumptions for possible energy use chart could be generated for a warm climatic region of Lagos, for the architectural energy efficiency when the characteristics that define energy use are established in the study area.

2.6 THEORETICAL AND CONCEPTUAL FRAMEWORK

Energy and building relationship are dynamic in nature, as explained by thermodynamic, which is defined as the science of the flow of heat and of its relationship to mechanical work. The first law of thermodynamic is the principle of conversion of energy. This law states that energy neither be created nor destroyed (except in sub atomic processes), but can only be converted from one form to another.

The second law of thermodynamics states that heat (energy) transfer can take place continuously in one direction only from a hotter to a cooler body or generally from a higher to a lower grade state.

Therefore, for any machine to perform work it must have an energy source and a sink that energy must flow through the machine, since only part of this flow can be converted into work. The flow from a high to a low temperature zone can take place in three forms: conduction, convection and radiation, Szokolay (2001). The built environment is formed by the buildings and other objects constructed in the natural environment. Modern buildings have various purposes, but can provide an internal environment different from the external. A climate of the natural environment, the shelter of the built environment, and human activities are linked by physical process. An outline of independence relationship is shown below. Mason and Hughes, (2001),

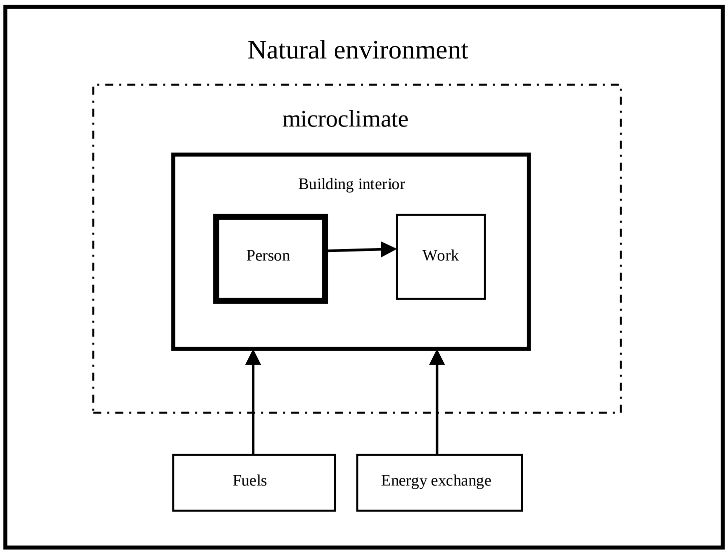


FIG. 2.18 Schematic diagram of the environmental relationships between people, building and local environment. *Source*: Nigel & Hughes (2001).

The thermal energy required for buildings is commonly obtained from fuels such as coal, gas and oil. Even if the energy is delivered in form of electricity, each must be converted to thermal energy in appropriate piece of equipment, such as boiler and heat distributed to the place of use. The amount of heat finally available to the users of a building therefore depends on the original energy content of the fuel and the efficiency of the system in converting and distributing this energy.

For this reason, the law of thermodynamics can be expressed by the idea of efficiency. For heating /cooling a building, the efficiency index or percentage can be calculated therefore by comparing the output power of energy with the input power of energy.

i.e.
$$\frac{\text{Efficiency (\%)}}{100} = \frac{\text{output}}{\text{input}} = \frac{\text{useful energy}}{\text{delivered energy}}$$

Generally, the useful energy is the output energy from the heating/cooling system, which is used to balance the heat losses and heat gains. In the same vein, the delivered energy is the input energy needed for the boiler, or other device, which is the energy paid for. The overall efficiency of the system therefore depends on how much of the pit is extracted from the fuel, how much is heat lost through the fuel and how much heat is lost in distribution system. Hence, the house efficiency is an approximate figure for domestic system that takes all this effects into consideration. For most buildings, energy need is an expression of energy balance.

Energy needed = thermal energy losses – thermal energy gains.

Therefore, the energy required to replace thermal losses or gains from the building represents a major portion of total energy consumption. This is expressed in FIG. 2.25 below:

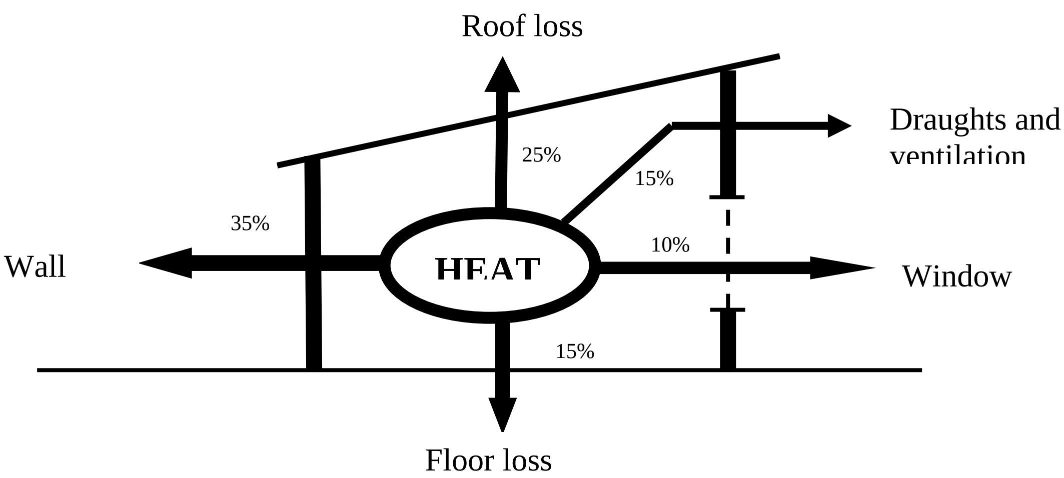


FIG. 2.19 Typical percentage energy losses from a traditional building.

(*Source: Nigel & Hughes (2001).*

In the light of the above, the study is able to derive its conceptual framework from a sustainability level of industrial revolution of a machine efficiency concept. For this reason, it is possible to relate the building to mechanical machines that manufacture their energy and utilize same to perform work. These works to include: heating, cooling, lighting and powering of appliances in buildings. This means that building can rightly source its energy from major renewable sources for electrical energy for purposes of cooling and lighting at the internal environment. Therefore, building energy efficiency is an expression of its ability to engage in heat balance and producing the needed energy to do the same. See Fig.2.26.

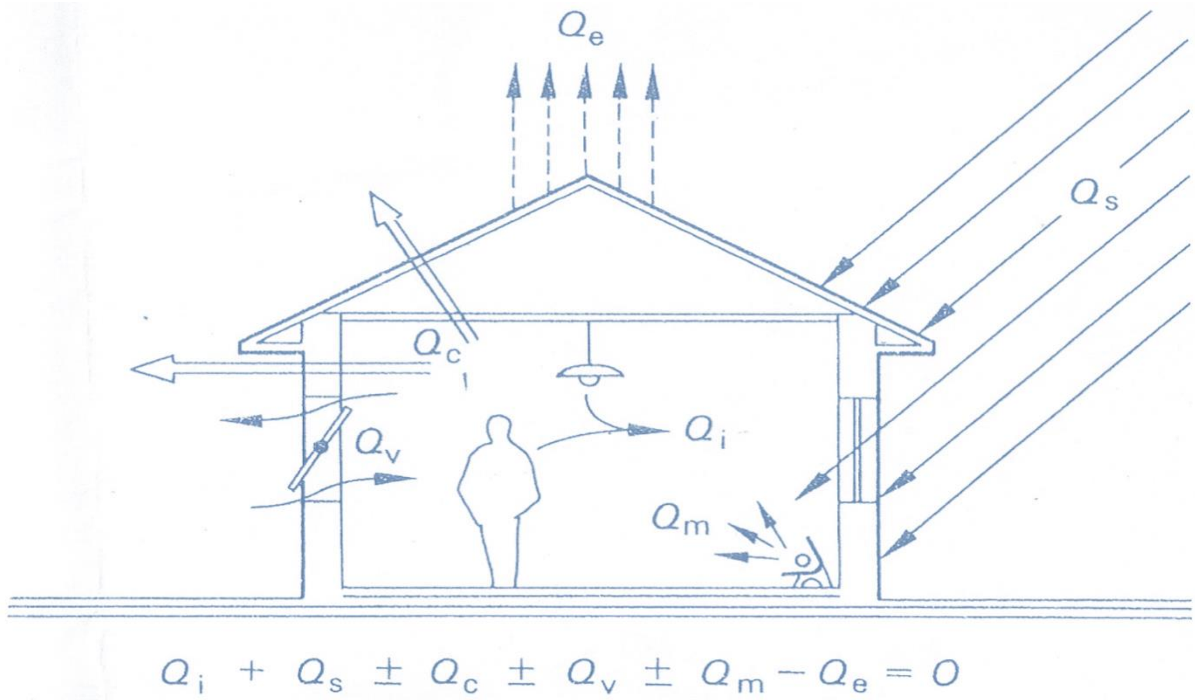


FIG. 2.20: Figure showing the Heat Exchange of Buildings

(*Source: Nigel & Hughes (2001).*

Therefore, heat balance is expressed as

Qi ± Qs ± Qc ± Qv ± Qm – Qe = 0

Where Qi = Radiation heat flow density in W/m^3

Qs = Radiation heat flow rate in W/m^2

Qc = Conduction heat flow rate in Watts

Qv = Ventilation Air Flow rate in m^3/S

Qm = Energy required for comfort in Kw/m^2

Qe = Evaporation heat flow rate in W/m^3

As heat flow rate through building elements is through conduction, it is given by

$Qc = A \times U \times AT$ 1

Where QC = conduction heat flow rate in Watts

A = surface area in m^2

U = transmittance value in $W/m^2\,^oC$

ΔT = temperature difference

While heat flow through windows (glassed or unglazed) is through radiation as given by

$Qs = A \times l \times \theta$

Where A = area of windows in m^2

l = radiation heat flow density in W/m^2

θ = solar gain factor of window glass

and heat flow rate between a building interior and exterior (open air) depends on ventilation rate as given by

$Qv = 1300 \times V \times \Delta T$

Where Qv = ventilation heat flow rate

1300 = volumetric specific heat of air; $J/m^3\,^oC$

V = ventilation rate in m^3/s

ΔT = temperature difference ^oC

If heat loss is

$Qi – Qc – Qv + Qm = 0$ 2

And heat gain is given by

$Qi + Qs + Qc + Qv + Qm = 0$ 3

No evaporation loss considered

The thermal balance equation (thermal design equation)

is given by

$Qi + Qs + Qc + Qv + Qm - Qe = 0$ 4

Therefore in a steady state,

$$Qi + Qs + Qc + Qv + Qe = Qm \qquad (5)$$

Where Qm = energy required for comfort

Assuming that Qms (energy supplied) = Qmc (enrgey consumed)

If machine efficiency,

$$\mathbf{E} = \frac{\mathbf{M.A}}{\mathbf{V.}} \qquad (6)$$

Therefore, building energy efficiency can be expressed as

$$\mathbf{E} = \frac{\mathbf{USEFULENERGY}}{\mathbf{DELIVERED}} = \mathbf{1} \qquad (7)$$

i.e $$\mathbf{E} = \frac{\mathbf{Qmc}}{\mathbf{Qms}} = \mathbf{1} \qquad (8)$$

Hence, equation 4 in linear form can be expressed as

$$\boxed{Q1k1 \pm Qsk2 \pm Qck3 \pm Qvk4 \pm Qmk5 \pm Qk = 0}$$

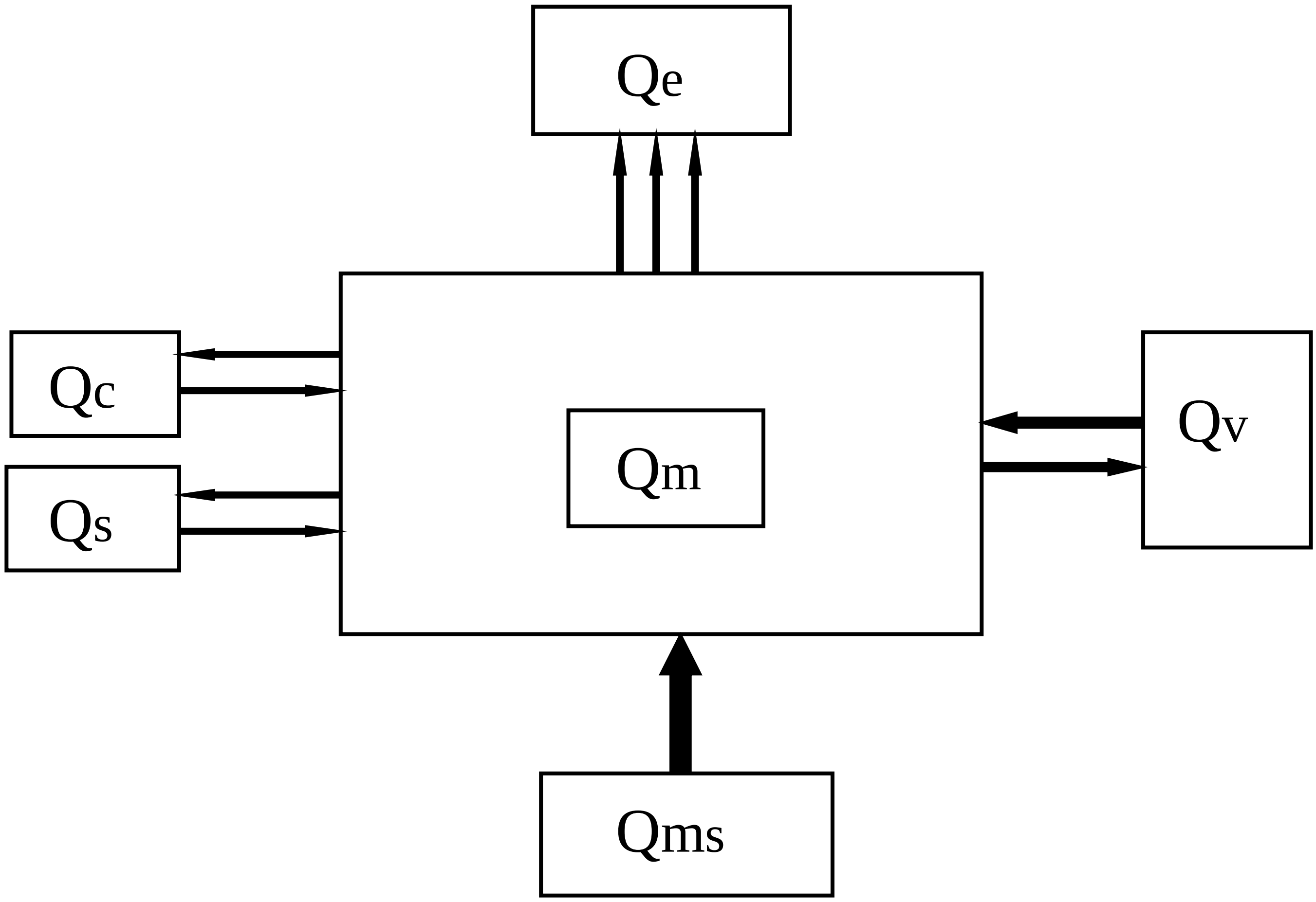


FIG. 2.21 Conceptual Diagram Showing the Energy balance Within a Building.

Where Qm = Energy used by household for Indoor Comfort

Qms = Energy supplied to household for comfort

Qe = Energy loss by building through evaporation to the environment

Qv = Energy gain/loss through ventilation

Qc = Energy gain/loss by conduction through building fabric

Qs = Energy gain/loss through glazed and unglazed surfaces

Murray (1978), Anderson *et. al*, (1977), Benjamin 1980, Selessar 1982, Jayce, 1989, and Wu 1988, contributions to this conceptual phenomenon identified specific limitations and appropriate uses of physical, economic thermodynamic and pure economic indicators of energy efficiency for different considerations. Identifying its importance as a policy objective is linked to commercial, industrial competiveness and energy security benefits as well as increasing to environmental benefits such as reducing Co_2 emission. This makes it relevant to the current study, as a physical indicator of thermodynamics, where consumers do not value the end use service on the basis of its heat content or work potential.

Under this application in the residential and commercial sectors, the most frequently used measure is energy input/square metre. This is because it does not present problem when it is used to measure aggregate energy efficiency performance of buildings. But fundamentally the energy input/m^2 or energy input/m^3 indicators are predicated on the idea that the main services delivered to the buildings are HVAC and lighting, which are directly proportional to square or cubic meters.

CONCEPTUAL FRAMEWORK

Architecture, as defined by Olumide (2004) in his inaugural lecture, is the art and science of design employed in solving problems in the built environment. With this standard definition of architecture, the energy consumption problem could be approached by considering the dynamic interrelationship of energy efficiency in the residential building sector from the interactions that exist between:

(1) Building Services

(2) Building Envelopes

(3) Human Factors

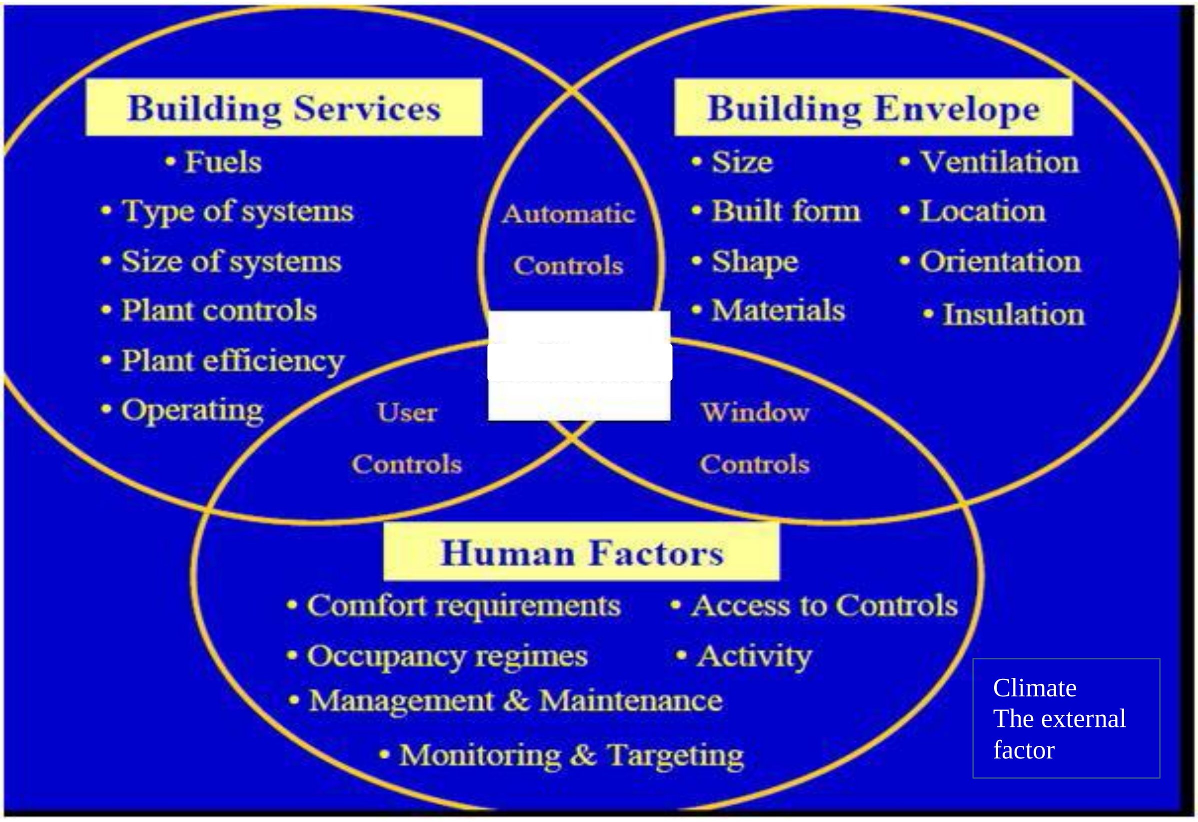


FIG. 2.22 Key factors that influence energy consumption

(Source: ICBSE Guide F.2004)

On the basis of the internationally acceptable integrated design concept for energy use in building, this is the ultimate goal of energy consumption study.

This study, therefore, adopts a conceptual framework that is driven by three major parameters. These parameters include:

(1) Environmental factors

(2) Building envelopes

(3) Human factors

Environmental Factors: These are thermal comfort determinates, sometimes refer to as climatic factor, which vary according to regional locations of built environment. There are six identified in research, out of which two are found to have impact on energy consumption. These are indoor and outdoor temperature and relative humidity, generally referred to as thermal characteristics of the environment or environmental variables.

Building Envelopes: This is the description of the physical components of the building characteristics. It is determined by such building elements as, External wall, window and door openings and the roof covering of the referenced building.

Human factors: This refers to the building occupants that determine energy consumption for their various uses at all time. Their behavioural actions, with respect to their occupancy rates, activities, comfort requirements, access and use of building's available control mechanism, to a greater extent, determine the amount of energy consumption by different households.

The energy consumption of any residential building can be determined by these three parameters. Inherent in the stated parameters are various variables that affect the amount of energy consumption of various types of houses. The environmental parameters are:

(1) Indoor and outdoor Temperature and humidity which are climatic and nature-driven.

(2) The building envelope variables include the building characters, as architectural design may dictate, usually determined by the building forms, size, and construction material component, opening for ventilation, location and orientation of buildings. These building features may be determined by all the built environment professionals from time to time and in accordance with micro and macro site settings.

(3)The third which is human includes variables such as the comfort requirements of the occupant as driven by their behavioural actions on available controls. The occupation rate at any particular time, the activity of the occupants and the energy target set for the building which is economically driven.

The interrelationship that may exist between these parameters and variables may go a long way in determining the amount of energy consumed by any household at all time, as explained in Fig 2.23 below.

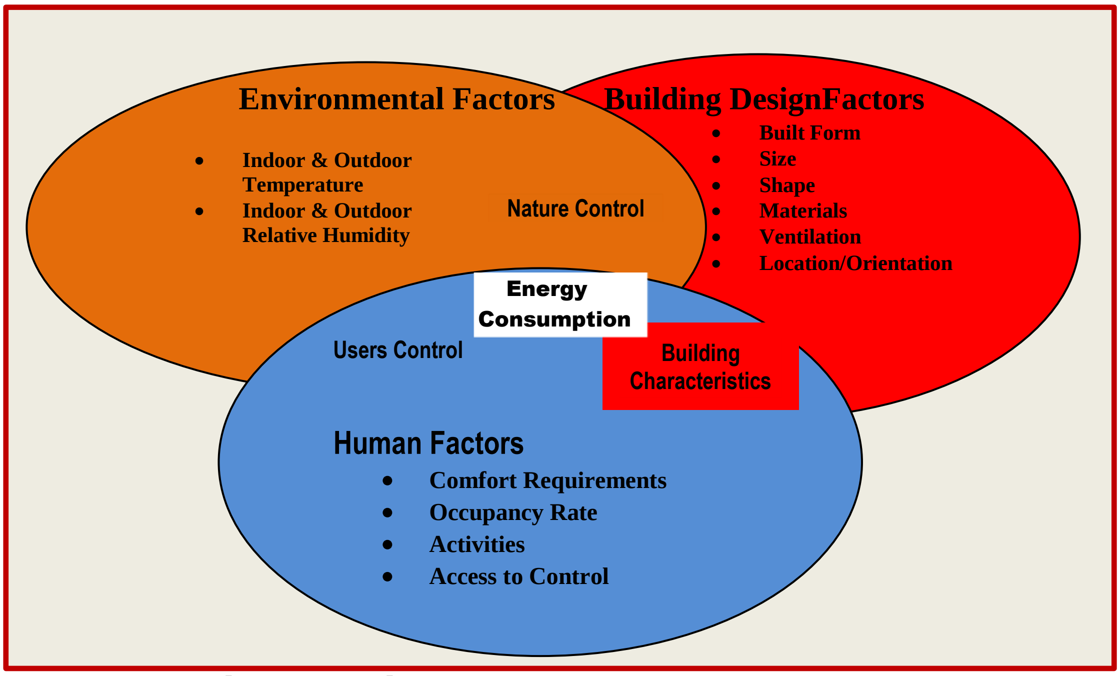


Fig 2.23: Conceptual Framework

This could be explained as the role of architecture in the design of energy efficiency in the building sector. This role, to Rahamatabadi and Toushmadani (2011), is better seen as an intermediate chain between the dynamic relationship that may exist between human factors, building services and building envelopes.

The study relates the 1st Law of thermodynamics, as seen by many, as central to the concept of energy conservation. The amount of energy that goes into a system cannot be lost along the way, but has to be used to do something, to either change internal energy or perform work. The 2nd Law of thermodynamics, similarly, deals not with how to undertake a task, but placing a restriction on what can be done. In practical terms, the law means that any heat engine or similar devices based upon the principles of thermodynamics cannot, even in theory, be 100% efficient. The study observed that energy efficiency then means, how much of a given amount of energy can be converted from one form to another useful form. In this study, reference to how much of energy consumption is used to do what is intended such as cooling, lighting and ventilation was compared to how much is lost or "wasted" as heat. The energy consumption can therefore be interpreted in terms of efficiency of energy utilization for optima resources as below:

$$\text{Energy efficiency} = \frac{\text{useful energy output}}{\text{Energy input}}$$

The scope of energy efficiency attainment or improvements refers to a reduction or optimal utilization in the energy used for a given service (cooling, heating, lighting and ventilation). Its importance as stressed earlier in various study and reports, as over 50% saving potential existing in the building sectors. This is considered as a potential factor in tackling the challenges posed by global energy supply and climate change scenario. Given this, what place has architecture in regulating the efficiency of energy consumption? The next chapter attempts to offer response to this question.

CHAPTER THREE:

RESEARCH METHODOLOGY, DATA COLLECTION AND ANALSIS

3.0 METHODOLOGY

This study adopts both case study and instrumental measurement with a survey research design involving quantitative and qualitative methods to assess energy consumption among households. Through this methodology, the basis for energy end use calculation was established. The quantitative method was used to analyse data on energy consumption, building information, micro environmental condition of the study area, thermal behaviour and control of residents. Likewise, the qualitative method centred on extensive review of relevant literatures. It also used instruments such as structured questionnaires administered on the residents. The matrix table is applied to present information obtained from the weather forecaster and monitored installed digital meters. Also aggregated data collected through structured questionnaire was modified to suit the study area for energy audit and possibly for simulation and modelling purposes. This will be applicable to explain the real life situation of the study area for further investigation whenever necessary.

The survey research design involved observation of the sample subject and variables without attempt to manipulate or control them (Asika, 1991). The process of carrying out these observations at one or more point at a time is referred to as Cross – sectional survey (Leedy1980, Zeizel 1986). On the other hand the longitudinal survey approach covering Wet and Dry seasons that was adopted with the energy audit structured questionnaire. This provides the study with quantitative and qualitative data for processing.

3.1 CASE STUDY APPROACH

The case study approach employed in this study provides the research with appropriate qualitative data of the building. It assesses building plans through ocular measurements and photographs’ at the same time identifies the various components of buildings characteristics and spaces. Yin (1994) defines case study research as an empirical enquiry that investigates contemporary phenomenon within its real life context, especially when the boundaries between the phenomenon and the context are not evident. Stake (1980), argues that case study is not a methodological choice of object to be studied. The object of study is a case, regardless of the method used. Hence, case study can be regarded as a research that incorporates several methods of data collection for analysis and processing of findings.

Yin (1994), further distinguishes two types of case studies as holistic and embedded. While holistic case study focuses on the case as a unit of analysis, embedded is one in which the case functions as the unit of analysis. However, there exist also sub-units of analysis with the case. In this study, residential buildings in the public and private housing estates of all residential neighbourhood densities types in the study area is the primary case, while different housing types surveyed are the embedded units of analysis. Therefore, the most preferred case study approach for this research is the embedded case study in which different housing types are involved.

This research adopted a multiple case design with embedded units. Yin (1984), distinguishes between a single case designed and multiple case designs. While a single-case design uses only one case to deal with the research questions, multiple case design uses two or more cases. Stake (1998), on the other hand, makes a distinction between three types of case study as intrinsic, instrumental and collective. Intrinsic case study provides better understanding of the particular case. An instrumental case study is one in which a particular case is examined to provide insight into an issue or refinement of a theory. Also, a collective case study is an instrumental study that is extended to several cases. Therefore, the case study for this research is instrumental and collective in nature, as it entails daily, weekly, and seasonal instrumental data collection for purpose of analysis.

The instrumentation method deliberately avoids making any alterations, so that results are applicable to normal conditions encountered by the respondents during the seasons of study. This involved the use of digital instrument (appendix I) and mobile internet application in each of all the audited households to collect environmental data of indoor and outdoor temperature and relative humidity. Also, the daily records of energy-use from the available energy suppliers installed digital and analogue meters in the case study buildings were undertaken. These were recorded for one week running in each of the sampled buildings for a period of six month in the year 2015.

3.1.1 STUDY POPULATION AND CHARACTERISTICS

The study is drawn from the residential neighbourhoods located in main urban communities in the sixteen metropolitan local government areas of Lagos. These communities are devoid of the state border settlements' influences, and have a fair representation of residential neighbourhood densities' of the study area, (see Fig. 1.2). The sixteen metropolitan local government areas identified consist of 564 urban communities that have a fair representation of three residential densities classifications and building types, consisting of both public and private estates and different social economic classes.

A stratified random sampling method that ensures a fair representation of all residential neighbourhood densities in terms of spatial spread, quantity and quality of information required was adopted. Thus, the study randomly selected different types of buildings from at least two major streets in each of the residential neighbourhood densities area of low, medium, and high densities for the energy audit and administration of questionnaires, (see Fig. 1.3). This was carried out between the months of February and December, 2015. The study also assesses 564 urban communities in Lagos metropolitan areas for a period of six months at an average of 25 houses in 20 residential neighbourhoods. Furthermore, the study sampled 609 residential buildings for the purpose of energy audit and administers questionnaires in selected households in the study area. These periods are also the rainy and dry seasons in the warm humid climate of Lagos Nigeria.

Since the population of study is a census of all items or subject that possess the same characteristics or that have the knowledge of the phenomena studied, the residential neighbourhoods considered include, both public and private neighbourhoods at different locations in the Lagos metropolitan area. These communities are supplied with active and passive energy by nature and national grid lines. They also consist of most housing types that are natural, mechanical and mixed mode ventilated residential buildings. The estates are also occupied by different household sizes and located within the warm humid climatic condition prevalent in Lagos.

3.1.2 POPULATION AND SAMPLE FRAME

This research is not a study of households' energy supply and demand. The focus is rather on the design parameters that determines households' energy consumptions in the residential neighbourhood of urban communities.

The households studied were from two residential housing types consisting of public and private houses, involving low, medium and upper income groups based in the metropolitan communities.

This is from a total population of 2,195,841 residential households made up of different house types in the sixteen metropolitan local Government areas, involving 576 urban communities (See Table 3.1). From this population, the sampling frame was obtained, while the sample of respondence used in the research was selected by random sampling techniques.

3.1.3 SAMPLING TECHNIQUES

This involves estimating the properties of the whole population by investigating a random sample taken from the population as widely used in statistical research. The random sampling, which ensures that each residential house type has the same probability/chance of selection from the urban communities, was used to obtain sample of households for measurements and energy audit. This was based on selecting every fifth alternate street and opposite buildings of households in the various residential neighbourhood area sampled.

SAMPLE SIZES: A sample size of 400 households is held to be adequate number of cases for a household population sample frame of 2,195,841, according to NBAAS (2012),as adjusted by Lagos State houses register (2015). This is in accordance with the sample size random statistical calculation method developed by Kotheri and Garg (2014) finite population formula at 95% confidence level and 0.05 acceptable error margins. This, however, conforms to Glenn D. Israel 2015 sample size table.

Considering, therefore, the cost in terms of time, money and availability of households for audit and respondences, it was decided by the researcher that at least a survey sample size of 609 households in the total sixteen metropolitan local Government areas is adequate. In order to get this required sample size, based on Ayandele (1996) quoted in Windapo (2005) findings that the response rate of questionnaires survey in Nigeria is very low and often less than 30%, a total of 609 were distributed to households in sixteen metropolitan local Government areas of Lagos.

Table 3.1: URBAN COMMUNITIES SAMPLED FRAME

S/N	LOCAL GOVERNMENT AREA	URBAN COMM	Tot. Sampled Household	Case Study			Building Type					
				Low	Medium	High	Detached	Sem. Dt.	Terrace	Blk. Flat	Bglw.	Rmh.
1	AGEGE	75	79	13	26	40	4	10	20	30	10	5
2	AJEROMI/IFELODUN	53	56	9	18	29	3	7	12	21	7	4
3	ALIMOSHO	29	30	5	10	15	2	4	8	10	4	2
4	AMUWO ODOFIN	12	14	2	4	8	1	2	3	5	2	1
5	APAPA	15	16	3	6	7	1	2	3	5	2	3
6	ETI-OSA	37	39	7	14	18	3	5	8	14	6	3
7	IFAKO-IJAIYE	34	36	6	12	18	3	6	8	12	4	3
8	IKEJA	38	40	7	14	19	3	6	12	10	6	3
9	KOSOFE	20	21	4	8	9	1	2	3	7	5	3
10	LAGOS ISLAND	56	59	10	20	29	4	8	14	21	8	4
11	LAGOS MAINLAND	56	59	10	20	29	4	8	14	21	8	4
12	MUSHIN	31	33	6	12	15	2	4	8	12	4	3
13	OJO	22	24	4	8	12	1	2	4	7	6	4
14	OSHODI/ISOLO	23	24	4	8	12	1	2	4	7	6	4
15	SHOMOLU	24	25	4	8	13	1	2	4	7	6	5
16	SURULERE	51	54	9	18	27	3	7	16	18	8	4
	TOTAL	576	609	103	206	300	37	77	141	207	92	55

3.1.4 RESEARCH VARIABLES INVESTIGATED AND INSTRUMENTATION

The following issues in the case study buildings were investigated apart from the design, as identified in the theoretical concepts.

1. Energy use record of households with reference to building design characteristics
2. Energy use indicators in the study area, with reference to comfort level in relation to energy consumption and living behaviour of households
3. Energy use reference to building elements and materials used for construction

In relation to these issues are some factors, variables and indicators for assessing the energy consumption of the case study building as enumerated in chapter three, section 2.54. For the purpose of this study, such factors include variables and indicators as;

1. Building design
2. Building elements and envelopes
3. Building facilities and equipment
4. Occupant thermal comfort control actions.

The measurement of the Environmental variables

The environmental variables are Air temperature, Mean radiant temperature and Relative Humidity. These are for both the outdoor and indoor conditions of the occupants, at two different levels of dry and rain/wet conditions respectively. This is to determine the effect of the occupant's behavioural actions on control mechanisms, as may be provided by building services design in order to establish the relationship of actions on energy consumption relative to indoor environments.

3.1.4.1 AIR TEMPERATURE AND MEAN RADIANT TEMPERATURE

The air temperature indoor varies from one spot to another in the indoor enclosure. Humphries (1973) observed that temperature measure near ceiling level in a classroom with warm air convector heater can be as much as 10^0k higher than the temperature experience by the children sitting on the floor Adebamowo (2007). This study is however concern with occupant's indoor temperature. The sitting comfort temperature is a better measurement of occupant's condition.

This study's indoor air temperature was measured on horizontal plain at a vertical height of 0.75m above the floor representing the height of the sitting condition. The digital weather forecaster and the downloaded application for weather measurements were used to measure both air and mean radiant temperatures. The readings were taken in degree centigrade (^oC) and recorded during the audit periods.

3.1.4.2 RELATIVE HUMIDITY (RH %)

The Relative Humidity (RH) is measured in the study using the same digital weather forecaster simultaneously. The RH is the amount of water vapour in the air expressed as a percentage of total water vapour which can be held in the air at a given temperature. From occupants' indoor comfort attainment point of view, this determines the operation of available control means within buildings that could impact on energy usage. On the other hand, relative humidity affects the behaviour of many building materials and their rate of deterioration. Givoni, (1976). This is measured using the digital weather forecaster which simultaneously records temperature together.

3.1.4.3 MEASUREMENT OF OCCUPANTS' BEHAVIOURS

The available buildings and energy consumption operative control mechanisms measure both objective and subjective occupants' behaviours for the attainment of indoor comforts. This is during dry and wet seasons. At this point, while one involves a passive control, the other is an active control and determines the amount of energy use for indoor comfort level attainable. This affected the rate of energy consumption of different types of houses, as observed from the monitored metre readings.

STUCTURED QUESTIONAIRE

The structured questionnaire (AppendixII) used in this study is adapted from residential energy performance survey (Santamouris (2005) and modified to suit the local context. This includes all relevant information, which this study seeks to investigate. The questionnaire is divided into six different sections:

SECTION A requests for general information of the buildings, the date, address, households, room, floor and time of conduct of survey. **SECTION B** requests for personal information of the respondent, such as gender, age, height, weight, activities within the last hour and clothing of the respondent. **SECTION C** requests for the general building information with respect to building year, retrofit or conversion or extension, building location, building type, building description, window and door types, glazing size and locations, roof type and roof overhang size, ventilation type and building plan or ocular measurement. **SECTION D** requests for information on environmental variables including indoor and outdoor temperature and humidity conditions. **SECTION E** requests for information on the occupant thermal behaviour and control. This involves window and air conditioner operations, clothing and shower actions. While the last section, **SECTION F** requests for information on electricity metre, alternative electricity supply, electricity availability time and electricity consumption recordings.

QUESTIONAIRE ADMINISTRATION

The questionnaires were distributed to the respondents with explanations of each section, while the readings of the environmental variables were taken by the researcher. The respondents were required to fill sections A, B, E and, where necessary, part of F. While information required in section A and B were easily comprehensible without difficulty, section E and F had to be properly explained to the respondents in order to obtain a reliable response.

3.2 PILOT STUDY

A pilot study was carried out in the three residential neighbourhood areas located at the University of Lagos. This specifically involved the staff quarters that are accessible for the purpose. It involved, in this regard, the four low rise major housing types, as in detached duplex, terrace, block of flats and bungalow. This provided a trial run for the instrumentation and questionnaire administered. It also involves testing the validity and reliability of the instrument as well as testing the technique use in the collection of data, and measuring the effectiveness of the standard invitation to respondence (Naomi, 1998).

The energy audit questionnaire used for this study was adapted from energy performance of residential buildings. Based on this, Santamouris (2005) model was modified by the researcher and two Professors in the Department of Architecture, University of Lagos. Additionally, the questionnaires' were first administered on households by five groups of two hundred level students of Architecture, University of Lagos, among the staff quarters residence, that serve as a pilot study. Criticisms and reviews were made to improve and modify the contents of the questionnaires with the supervisor.

The summary result of measurement and findings is as stated below. This is intended to be used as a control guide for this study's final field work

Mean Average Temperature	26.7^0c
Average Relative Humidity	81%
Mean Average weekly Energy Consumption	45.3KWh
Mean Average hourly Energy Consumption	0.27KWh

3.3 FIELD SURVEY

The primary data for this survey were collected through field survey by using modified standard energy questionnaires. This method of questionnaire involved 434 buildings and Households with three categories of respondences referred to as occupants between April and December 2015.

Since it was not practicable to reach the entire households in the study area, sample was therefore taken, considering the magnitude of this study. Thus, the samples were drawn from two main groups. The first group involves households which consist of three categories of respondence single family unit, twin family units and multiple family units. The second group was the residential buildings type that consists of both private and public residential buildings table. They include different types of residential buildings found in Lagos metropolis such as detached houses, semi-detached houses, terrace houses, block of flats, bungalows and rooming houses (Tenant Home/Brazilian Types). However, considerations were only given to low rise buildings i.e. (one to 3 storey buildings) in the study since they constitute the majority of residential buildings within the study area. The household group distribution with respect to gender and age were generally unbiased but based on respondent available at the time of audit. While house types were as result of accessibility.

Table 3.2: Household Group Distribution

	Gender/Sex	Households
	MALE	294
	FEMALE	140
	TOTAL	434
	AGE	**HOUSEHOLDS**
	0 – 20	34
	21 -50	322
	51 – 70	95
	TOTAL	434

Table 3.3: Residential Houses Distribution

	DESCRIPTION	DISTRIBUTIONS	PERCENTAGE
	Detached Houses (Duplex/DD)	42	9.7
	Semi – Detached Houses (SD)	19	4.4
	Terraces(TC)	36	8.3
	Block Of Flats (BF)	152	35.0
	Bungalow (BG)	92	21.0
	Rooming House (FF)	93	21.4
	TOTAL	434	100

This study used the random sampling technique so as to ensure that each type of house has the same chance of selection. The households audited comprise houses and occupants of selected residential building units from the 434 different houses in various residential neighbourhoods found in the 556 urban communities in Lagos metropolis, as shown in Table

3.1. These have an average of three respondents in each building, making up a total of 1302 correspondences that were used.

The Instruments were set up in living rooms of selected houses for the measurements of indoor conditions and later outside to measure the outdoor conditions before taking measurements of temperature and relative humidity. These usually take place within the hour of 8.00am to 5.00pm every hour, then a daily average is taken. The adherence to this specific time frame was due to limited accessibility to residences at periods other than this and to give regard to the privacy of occupants.

While the measurements of instruments were taken by the researcher, occupants were assisted to complete the questionnaires that have been distributed earlier and explained to household occupants' by auditors. However, daily readings of energy used from the electricity supplier's meter were also taken by auditors for a period of one week in the case of non-literate occupants, while literate ones help to record their own consumptions for a week running. The inclement weather during wet season as accompanied with flooding situation in the study area was greatly responsible for the unequal numbers of houses participation between dry and wet seasons.

Table 3.4: Sampling Distribution

Number of Participants	Rain Session	Dry Session
	256	353
Number of Houses	256	353
Period of Survey	10th April- 10th October 2015	15th October – 15th December 2015
Time of Survey	08:00am – 6:00pm	08:00am – 6:00pm

Both subjective and objective measurements were also taken simultaneously. While the subjective measurements involved the buildings ocular survey and physical measurements of buildings descriptions, the objective measurements involved occupants' data on personal parameters (thermal comfort behaviour), and the environmental parameters (indoor and outdoor) temperature and relative humidity.

3.4 DATA COLLECTION

Primary data were collected with the use of electronic instrument for environmental variables, while energy consumption readings were collected through the electricity supplier digital metres installed in each of the case study sampled houses. The semi-structured questionnaire for obtaining subjective measurements was done with the assistance of the energy audit team personnel.

Secondary data for energy consumption were obtained from members of households surveyed. While the environmental variables data were obtained from the Nigerian Metrological Agency, (NIMET), Oshodi. This includes daily weather records of average temperature and humidity.

The energy audit questionnaire used for this study was the modified semi structured questionnaire developed by Santanmouris (2005), and modified by the researcher with the authority of the supervisor of this research.

3.4.1 DATA COLLECTION STRATEGIES: Data collection strategies were divided into mixture of qualitative and quantitative approaches. The following combination of data collection strategies was adopted for the study.

1. Quantitative and qualitative physical survey of case studyof sample building types through building plans or physical measurement of building elements.
2. Qualitative and quantitative semi-structured interaction with open and close questionnaires.
3. Quantitative measurement of energy consumption through electricity supplier installed metres

4. Quantitative measurement of indoor/outdoor environmental variables factors of temperature and humidity through wireless weather forecaster and internet weather application.
5. Photographs of case study buildings for quantitative records.

3.4.2 DATA ANALYSIS

A data analysis sheet prepared was used in the preparation and collation of extracted data from completed returned questionnaires. Data collected were nominal, ordinal interval and ratio scale. Different analytical techniques were used to determine the direction of the study using SPSS 21 software programme. The descriptive statistics for the variables used include mean (X), median, frequency of occurrences and simple percentages (%). The inferential statistical method of analysis includes: bivariate analysis explaining the relationship and contributions of variables on energy consumption. Also, Chi-Square test, Pearson product moment correlation (r), Spearman rank correlation coefficient (Rho) and multiple regression analysis aid the analysis of data. These analyses were conducted to provide explanation for the objectives of this study in order to determine their relevance or otherwise. Analysis was also done to reveal possible relationship, differences, contributions and dependencies between the variables in the study. This was done to ascertain if the results obtained were significant.

CHAPTER FOUR:

DATA PRESENTATION AND ANALYSIS

This chapter is primarily concerned with the presentation of data collated from the different questionnaires administered on households. Analysis of data, discussion of findings and any relevant observation made during the course of the survey were also presented.

The analytical process included sorting out data, summarizing the data and finally making inferences, involving the use of appropriate statistical tools. The analysis was done using computer – based Statistical Package for Social Sciences (SPSS 21). This enhances possible testing of the statistical significance of the stated objectives.

4.1 DATA PRESENTATION

The collated data from the questionnaires were sorted out, summarized into tables and in some cases involve graphical representation of the responses, followed by each variable.

4.1.1 RESPONDENT INFORMATION

The study identified if the gender, age and activities of respondents has any effect on the energy consumption, as presented in Table 4.1.

From Table 4.1, it can be seen that 67.7% of respondence were male, while 32.3% were female. Also, 81.3% are middle age as 10.8% were 50 years and above while, 7.8% represent young age occupants. However, their activities were mostly dominated by exercise 29.5%, closely followed by relaxation of 29%, while working represents 21%, sleeping 11.1% and reading activity accounted for 9.4%.

Table 4.1: PERSONAL INFORMATION OF HOUSEHOLDS.

GENDER	NO. OF RESPONDENTS	PERCENTAGES (%)
Male	294	67.7
Female	140	32.3
Total	**434**	**100**
AGE	**NO. OF RESPONDENTS**	**PERCENTAGES (%)**
<20	34	7.8

21-50	353	81.3
>50	47	10.8
Total	**434**	**100**
ACTIVITIES	**NO. OF RESPONDENTS**	**PERCENTAGES (%)**
Working	91	21.0
Sleeping	48	11.1
Reading	41	9.4
Sport/exercise	128	29.5
Relaxing	126	29.0
Total	**434**	**100.0**

4.1.2 BUILDING CHARACTERISTICS

The study sought to find out if the buildings characteristics affect energy consumption of the respondents. This is presented in Table 4.2.

From Table 4.2, it can be seen that 76% of the sample building are located in urban areas, while neighbourhood representation accounts for 21%. The building type is dominated by 35% block of flats, 21.4% rooming houses, 21% bungalows with 9.7% detached houses, 8.3% terraces and 4.4% semi-detached houses. Building orientation is dominated by 35.3% NS, 29.3% EW as SW/NW is 18.4% while NE/SW, accounted for 17.1% orientation. The building main ventilation modes were 47.2% natural ventilation system, with mixed mode ventilation of 44.9%, while mechanical ventilation accounted for 6.5%.

Table 4.2: Building Characteristics

	BUILDING LOCATION	**FREQUECNY**	**PERCENTAGES (%)**
BUILDING LOCATION	Local Government	3	0.7
	Neighbourhood	91	21.0
	Urban Area	330	76.0
	Suburban Area	9	2.1
	Others	1	0.2
	Total	**434**	**100**
BUILDING TYPES			
	Detached house	42	9.7
	Terrace	36	8.3
	Semi-detached house	19	4.4
	Block of flats	152	35.0
	Bungalow	92	21.2
	Rooming house	93	21.4
	Total	**434**	**100**

BUILDING ORIENTATION			
	North South	153	35.3
	East West	127	29.3
	South East / North West	80	18.4
	North East /South West	74	17.1
	Total	**434**	**100**
BUILDING VENTILATION MODE			
	Natural ventilation system	205	47.2
	Controlled ventilation system	5	1.2
	Mechanical ventilation system	28	6.5
	Balanced ventilation system	1	.2
	Mixed mode ventilation system	195	44.9
	Total	**434**	**100**
BUILDING FORM			
	Triangular	7	1.6
	Rectangular	410	94.5
	Square	16	3.7
	Polygon	1	.2
	Total	**434**	**100**
OCCUPANCY RATE			
	1-5	277	63.8
	6- 10	141	32.5
	3	16	3.7
	Total	**434**	**100**
ROOF TYPE			
	Flat	69	15.9
	Gable	266	61.3
	Hip	92	21.2
	Others	7	1.6
	Total	**434**	**100**

4.1.3 BUILDING CONSTRUCTION MATERIALS

The contribution of the construction materials characteristics of households to energy consumption as described by Walls, Roof, Ceilings, Windows, Colour, form, Occupancy rate and roof types. The view of respondents is as stated in Table 4.3 below.

It can be deducted from table 4.3 that household's wall material is represented by 89.9% hollow sandcrete blockwall, 8.3% solid brickwall and 1.6% concrete wall. The roof is dominated by corrugated asbestors 47.2%, Iron sheet 26.0%, Aluminium 23.5%, as reinforce concrete represents 1.2% of the roofing materials used in the construction of sampled houses population. The ceiling materials were made up of 65% asbestors, 10.8% P.O.P, wooden of 10.1% as 4.8% represents U.P.VC, while the window openings materials were mostly 96.8% single glazing as only 1.8% of households uses double glazing windows.

The colour of ceiling is dominated by white colour paint of 84.3%, as wall paint is dominated by cream 26.3%, while other mixture is represented by 31.5% as white, blue, yellow and green coloured walls have 10.1%, 8.1%, 8.3%, and 12% respectively.

Table 4.3: BUILDING CONSTRUCTION CHARACTERISTICS

	DESCRIPTION	**FREQUECNY**	**PERCENTAGES (%)**
WALL	Solid brickwall	36	8.3
	Hollow sandcrete blockwall	390	89.9
	Concrete wall	7	1.6
	Others	1	0.2
	Total	**434**	**100**
ROOFS			
	Corrugated Asbestors	205	47.2
	Corrugated Aluminium	102	23.5
	Corrugated Iron sheet	113	26.0
	Reinforced concrete slab	5	1.2
	Others	9	2.1
	Total	**434**	**100**

CEILINGS	Asbestors	282	65.0
	Wooden	44	10.1
	P.O.P	47	10.8
	U.P.V.C	21	4.8
	Others	40	9.3
	Total	**434**	**100.0**
WINDO WS			
	Single Glazed	420	96.8
	Doubled Glazed	8	1.8
	Others	6	1.4
	Total	**434**	**100**
CEILING COLOUR	**DESCRIPTION**	**FREQUECNY**	**PERCENTAGES (%)**
	White	366	84.3
	Blue	6	1.4
	Red	1	0.2
	Yellow	3	0.7
	Green	3	0.7
	Cream	11	2.5
	Others	44	10.1
	Total	**434**	**100**
WALL COLOUR			
	White	44	10.1
	Blue	35	8.1
	Red	16	3.7
	Yellow	36	8.3
	Green	52	12.0
	Cream	114	26.3
	Others	137	31.5
	Total	**434**	**100**

4.1.4 APPLAINCES AND EQUIPMENT

The acquisition of household’s appliances and equipment as collected data with respect to energy consumption is as shown in Table 4.4.

Table 4.4 shows that households’ external lighting fittings represent 97.7% of the population as 2.3% are without fittings. The use of electric cooker in households is found to be 51.2%, while 48.8% do not make use of it. The washing machine use is 48.2% in households and 51.2% are without washing machine. Only 5.1% household is fitted with pool heater and pump, as against 94.9% who do not have fitted pool heater. External sauna represents 1.2%

use and 98.8% are non-fitted. Fan acquisition and use is 99.5%, while 0.5% households were without fans. Air-conditioner use was 52.5%, as 47.5% households were without air-conditioners. While 79.5% of households use refrigerators, only 20.5% households do not use it.

Table 4.4: HOUSEHOLDS' APPLIANCES AND EQUIPMENT

DESCRIPTION	RESPONE		TOTAL RESPONSES	PERCENTAGES (%)		TOTAL %
	YES	NO		YES	NO	
EXTERIOR LIGHTING	424	10	434	97.7	2.3	100
ELECTRIC COOKER USE	222	212	434	51.2	48.8	100
WASHING MACHINE USE	211	222	434	48.6	51.2	100
POOL HEATER PUMP	22	412	434	5.1	94.9	100
EXTERIOR SAUNA	5	429	434	1.2	98.8	100
FAN USE	432	2	434	99.5	0.5	100
AIR-CONDITIONER USE	228	206	434	52.5	47.5	100
REFRIGERATOR USE	345	89	434	79.5	20.5	100

4.1.5 ENVIRONMENTAL TEMPERATURE AND RELATIVE HUMIDITY MEASUREMENTS

The study sought to observe and measure the environmental factors of temperature and relative humidity of outdoor and indoor household's macro-climates in order to examine its impact on energy consumption of households.

Table 4.5 shows that a maximum of 37.5^0c of outdoor temperature were observed with a mean value of 28.5^0c and frequency occurrence of 26^0c. At the same time outdoor relative humidity maximum of 95RH were observed as having a mean value of 66.72RH and frequency mode of 70RH. The indoor maximum households' observations for radiant temperature were 34.2^0c, a mean value of 28.63^0c and frequency mode value of 24^0c. The indoor relative humidity of maximum 91RH was observed with 64.26RH mean value.

Table 4.5; TEMPERATURE AND RELATIVE HUMIDITY MEASUREMENTS

DESCRIPTION	MEAN	MEDIAN	MODE	MINIMUM	MAXIMUM
OUTDOOR RADIANT TEMPERATURE	**28.56^0**	**29^0**	**26^0c**	**0^0c**	**37.5^0c**
OUTDOOR RELATIVE HUMIDITY	**66.72RH**	**70RH**	**74RH**	**0RH**	**95RH**
INDOOR RADIANT TEMPERATURE	**28.63^0**	**28.9^0**	**24^0c**	**0^0c**	**34.2^0c**
INDOOR RELATIVE HUMIDITY	**64.26RH**	**70RH**	**0**	**0**	**91RH**

4.1.6 OCCUPANTS' ACCESS AND CONTROL USES OF BUILDING OPENINGS

The study sought to examine the timing of behaviour response of occupants so as to access and use available design control means for comfort. This is as reflected in Table 4.6.

The responses as shown in table 4.6 show that 62.7% use control in the morning time, while 13.1% of respondents use it in the evening between (19-24hr). 11.5% operate it in early evening period between (19-18hr), as only 4.6% use it in the night. Others that do not make use of control represent 7.8% of the respondents.

Table 4.6: ACCESS AND CONTROL USE TIME

TIME OF USE	FREQUENCY	PERCENTAGE (%)
Morning 07-12hr	272	62.7
Evening 19-18hr	50	11.5
Evening 19-24hr	57	13.1
Night 01-06hr	20	4.6
Others	34	7.8
Total	**433**	**100**

4.1.7 THERMAL BEHAVIOURAL ACTIONS (DRY AND RAINY CONDITION)

The study also sought to examine the thermal behavioural actions of the respondents during dry and rainy weather conditions. The results are presented in Tables 4.7 and 4.8 below.

It can be understood from Table 4.7 that 38% of the respondents switch on air-conditioners during hot and humid conditions, while 35.3% switch on fan, 11.8% open windows and doors, while 5.8% take more bath. Likewise, 2.5% take more cold drinks and only 1.2% changes their clothing.

With the cold condition however, 59% switch off fans, 15.9% close their windows, 9.0% turn up some lighting fixtures, while 6.5% take hot shower and change to heavy clothing. Only 2.1% of respondents cuddle up, as other 1.2% adopts different means to get comfortable.

Table 4.7: DRY WEATHER CONDITIONS BEHAVIOURS

DESCRIPTION (DRY)	FREQUENCY	PERCENTAGE (%)
Take bath more often	25	5.8
Change cloth to light clothing	5	1.2
Get more cold drink	11	2.5
Open window and door wide	51	11.8
Switch on fan	153	35.3
Switch on air conditioner	165	38.0
Go outside for fresh air	24	5.5
Total	**434**	**100.0**

Table 4.8 RAINY WEATHER CONDITIONS BEHAVIOURS

DESCRIPTION (RAINY)	FREQUENCY	PERCENTAGE (%)
Take a hot shower	28	6.5
Change my cloth to heavy clothing	28	6.5
Closing the windows	69	15.9
Switch off the fan	256	59.0
Turn up some lighting fixtures	39	9.0
Curling up or cuddling up	9	2.1
Others	5	1.2
Total	**434**	**100**

4.2 Objective 1: BUILDING CHARACTERISTICS

To examine the characteristics of selected residential buildings with respect to their energy consumption in Lagos metropolis; Data collections relating to building elements identification were collected. This was done through Photographs of the case study of building types and location, form and construction materials. Physical measurements of building envelope elements were also taken. This includes area of external doors and windows in all directions, floor building areas, circumference, and volumes of sampled buildings. Data analyses involved descriptive and inferential statistical methods used to obtain variables frequencies, mean averages and modes. Chi-square test for numeric and non-numerical variables were conducted to establish relationship with weekly energy consumption. The result shows that out of twenty-two variables tested seventeen of the variables are found significant to energy consumption in the study area, as shown in Table 4.9 below.

Table 4.9 Relationships Between Building Characteristics and Energy Consumption.

S/N	TEST VARIABLES	P-VALUE	INFERENCE
1.	Weekly Energy Consumption VS Building location	0.000*	Significant relationship
2.	Weekly Energy Consumption Vs. Building orientation	0.001*	Significant relationship
3.	Weekly Energy Consumption vs. Building form	1.000	No significant relationship
4.	Weekly Energy Consumption vs. Main type of ventilation	0.000*	Significant relationship
5.	Weekly Energy Consumption vs. Building Roof type	0.000*	Significant relationship
6.	Weekly Energy Consumption vs. Roof material	0.051	No significant relationship

7.	Weekly Energy Consumption vs. Wall material	0.505	No significant relationship
8.	Weekly Energy Consumption vs. Type of windows	0.744	No significant relationship
9.	Weekly Energy Consumption vs. Total area glazed of external doors and Windows	0.022*	Significant correlation
10.	Weekly Energy Consumption vs. Total size of glazed Window	0.000*	Significant correlation
11.	Weekly Energy Consumption vs. number and area of windows in North East	0.000*	Significant correlation
12.	Weekly Energy Consumption vs. number and area of window in South West	0.000*	Significant correlation
13.	Weekly Energy Consumption vs. number and area of window in South East	0.000*	Significant correlation
14.	Weekly Energy Consumption vs. number and area of window in North West	0.001*	Significant correlation
15.	Weekly Energy Consumption vs. size of roof eave	0.001*	Significant correlation
16.	Weekly Energy Consumption vs. Building circumference external dimension	0.000*	Significant correlation
17.	Weekly Energy Consumption vs. Building Longest Length external Dimension	0.000*	Significant correlation
18.	Weekly Energy Consumption vs. Building envelop external dimension	0.018*	Significant correlation
19.	Weekly Energy Consumption vs. building total area internal dimension	0.005*	Significant correlation
20.	Weekly Energy Consumption vs. building heated floor area internal dimension	0.000*	Significant correlation b
21.	Weekly Energy Consumption vs. Residential cooled floor internal dimension	0.000*	Significant correlation
22.	Weekly Energy Consumption vs. Total volume of building external dimension	0.108	Significant correlation

4.3 Objective 2: ENERGY CONSUMPTION INDICATORS

To identify energy consumption indicators of residential buildings in Lagos metropolis. Data collections relating to energy consumption were collected daily through installed digital metres records in households at 24hrs intervals and recorded on administered questionnaires. In the same way, data analyses were conducted on identified building characteristics to ascertain their relationships and correlation with energy consumption. These are design indicator variables in (1) above using their p-values. Thus, the variables with an asterisk are the relevant indicators of energy consumption in the residential buildings, since they show a relationship in the form of non-numerical variables and correlation as in numerical variables.

BUILDING DESIGN INDICATORS: Seventeen out of twenty-two identified building characteristics constitute the building design indicators in the study area, as shown in Table 4.9. Among these are four that shows significant inverse and direct proportional relationship with energy consumption, they includes General size of windows, Building envelope, Internal residential cooled floor area and Total glazed area of external doors and windows as in FIG 4.1,4.2,4.3 and 4.4.

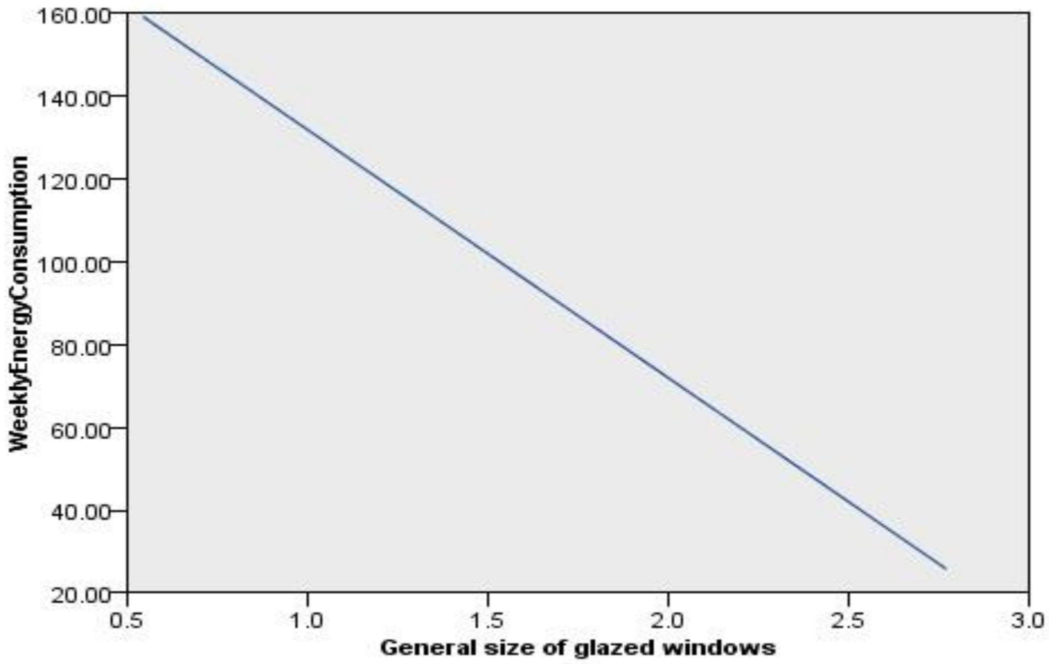


FIG. 4.1 Relationship between Households' Energy Consumption and General size of Windows.

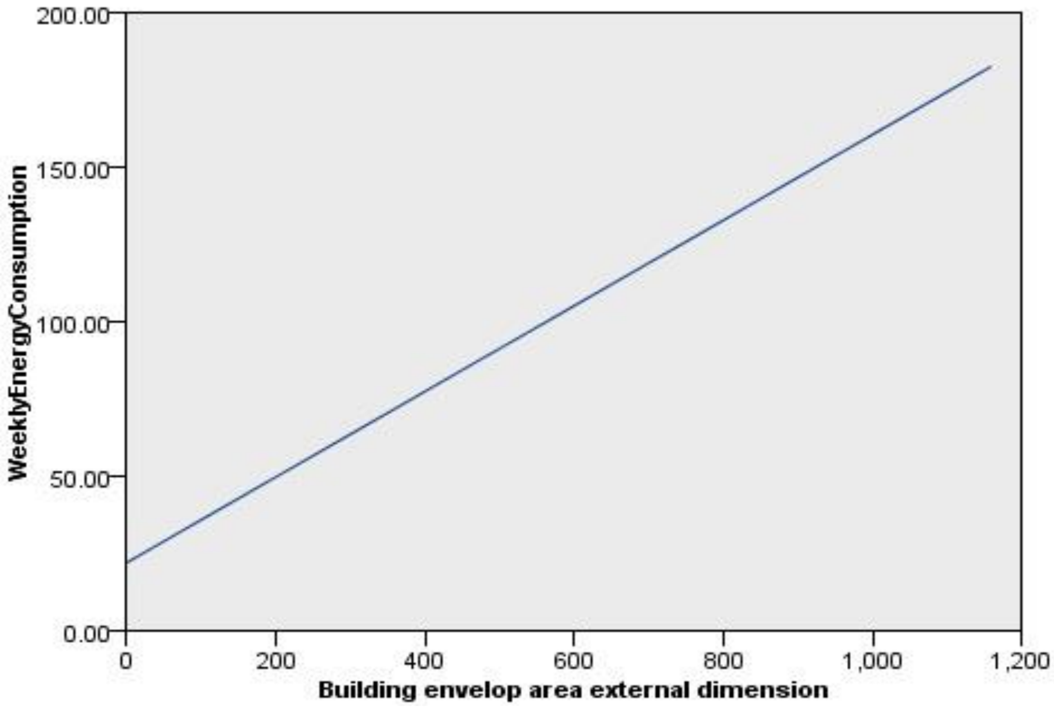


FIG. 4.2 Relationship of Building Envelope to Energy Consumption.

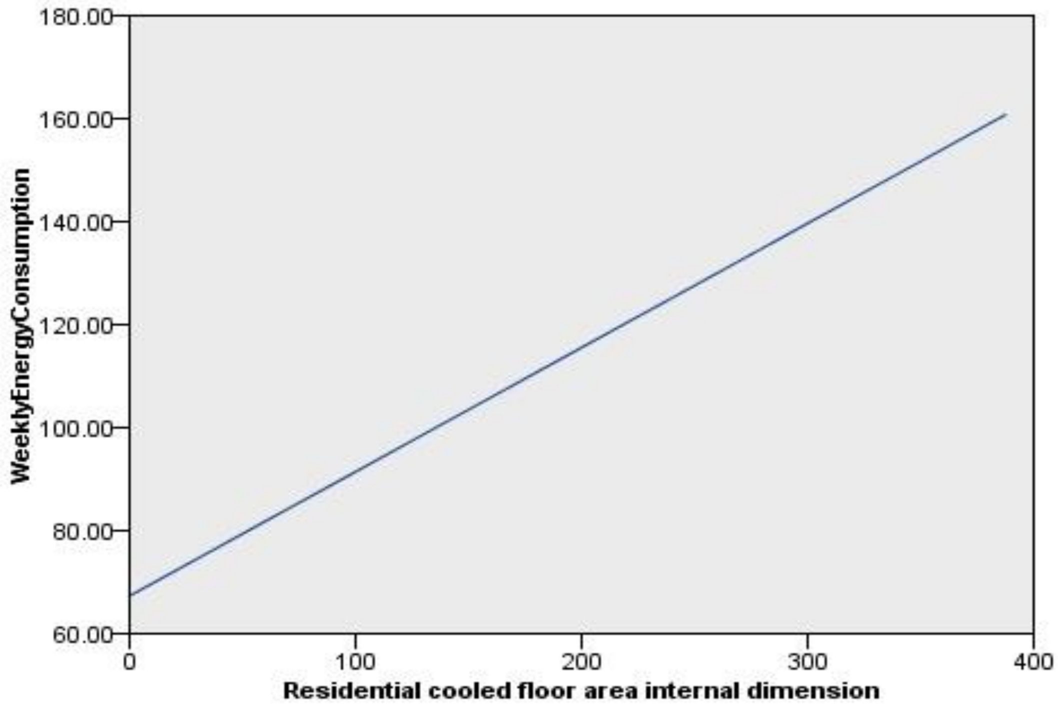


FIG. 4.3 Relationship of Internal Cooled Floor Area and Energy Consumption.

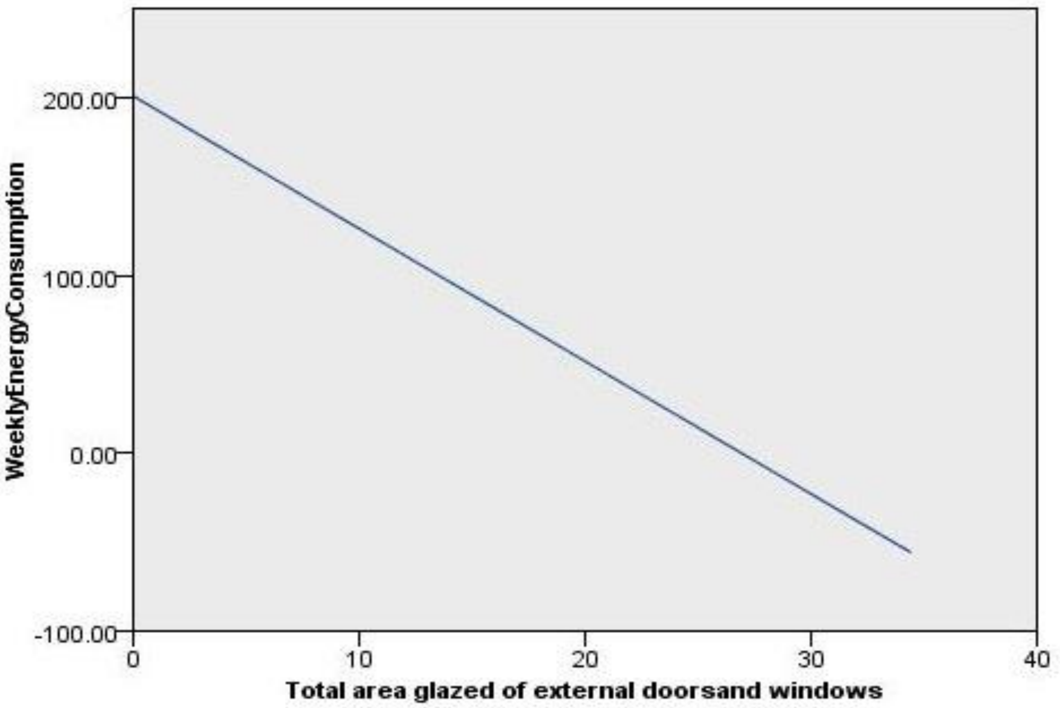


FIG. 4.4 Effect of External Glazing on Energy Consumption.

4.4 Objective 3:ENVIRONMENTAL FACTORS AND ENERGY CONSUMPTION.

To examine the impact of environmental variables on occupant's use of design controls in residential building towards energy consumption. Data collection involves measurements of indoor and outdoor relative humidity, outdoor and indoor radiant temperature. These were collected with the aid of electronic weather forecaster and weather internet application.

Data analyses were done with the aid of spearman correlation so as to determine the strength of the relationship between the variables and arrive at a conclusion on which variable had impact. We test at $\alpha = 0.05$ against our P- value.

TABLE 4.10 Relationships between Environmental Factor Indicators and Energy Consumption

S/N	TEST VARIABLES	P-VALUE	INFERENCE
23	Weekly Energy Consumption vs. Outdoor mean radiant temperature	0.093	No significant correlation
24.	Weekly Energy Consumption vs. Outdoor relative humidity	0.001*	Significant correlation
25.	Weekly Energy Consumption vs. Indoor mean radiant temperature	0.000*	Significant correlation
26.	Weekly Energy Consumption vs. Indoor relative humidity	0.255	No significant correlation

Estimated Means

Target: Weekly Energy Consumption

Estimated means charts for the top ten significant effects (p<.05) are displayed

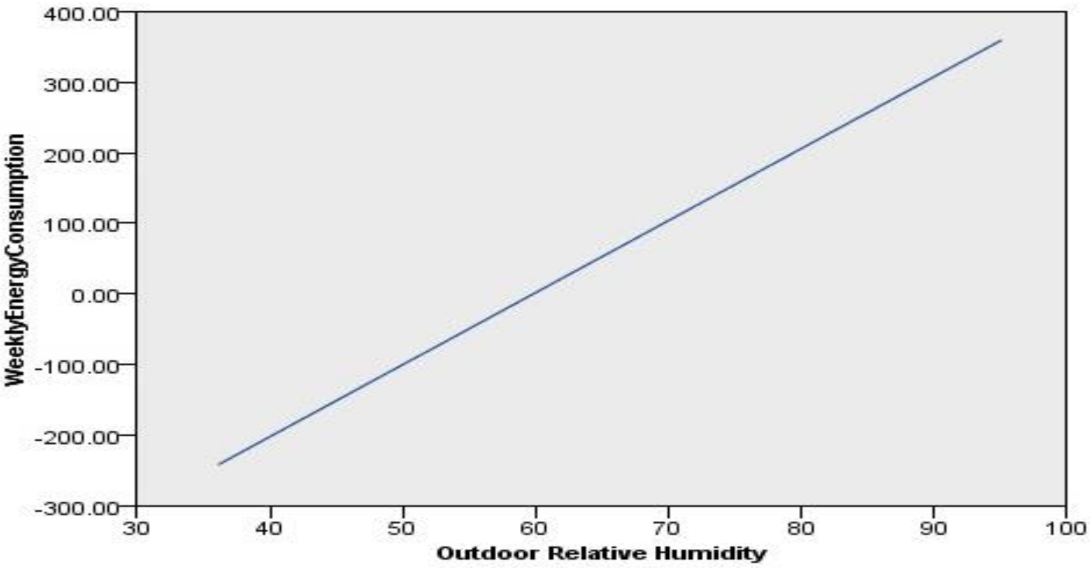


FIG. 4.5 Effects of Outdoor Relative Humidity on Energy Consumption**.**

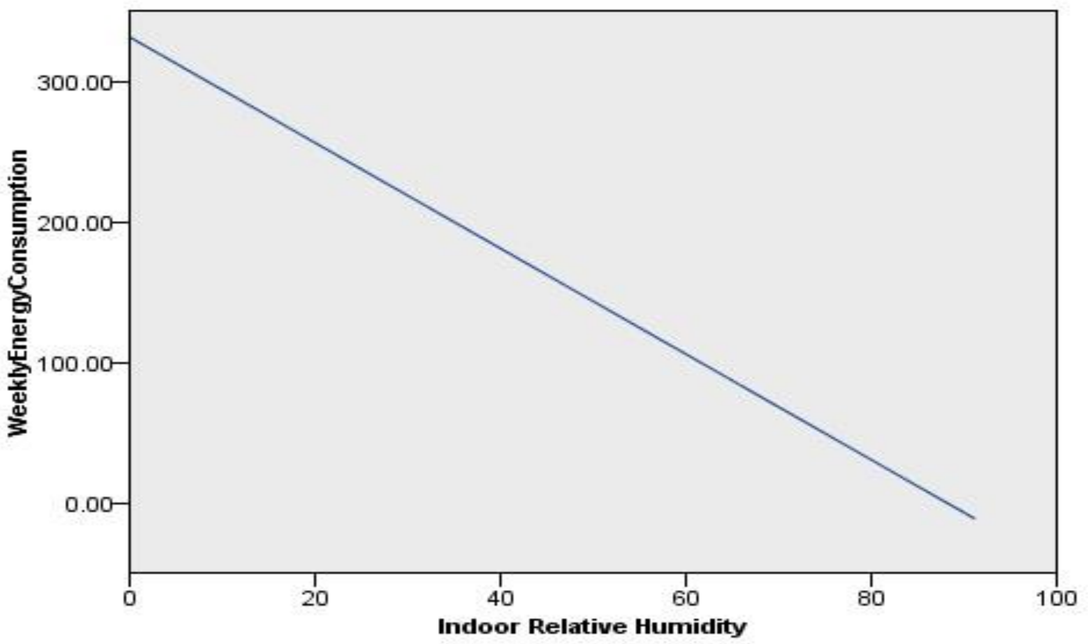


FIG. 4.6 Indoor Relative Humidity Effects on Energy Consumption

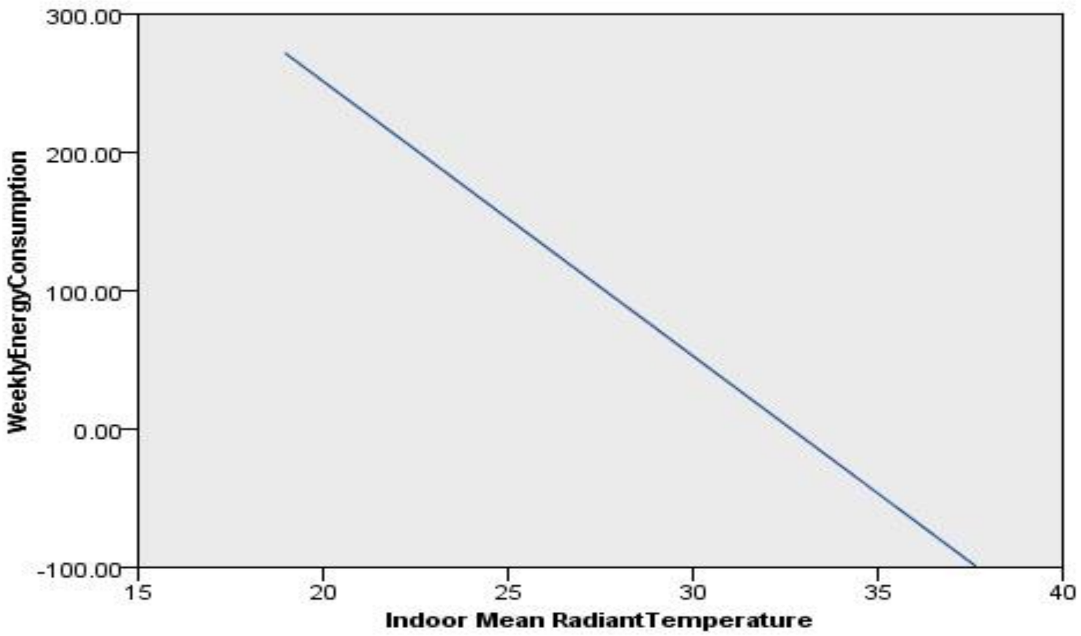


FIG. 4.7 Effect of household's Indoor Temperature on Energy Consumption.

TABLE 4.11 Relationships between Environmental Factors and Control Actions

S/N	TEST VARIABLES	P-VALUE	INFERENCES
1.	Living room window open time vs. Outdoor mean radiant temperature	0.000*	Significant correlation
2.	Living room window open time vs. Outdoor	0.000*	Significant correlation

	Relative Humidity		
3.	Living room window open time vs. Indoor mean Radiant Temperature	0.000*	Significant correlation
4.	Living room window open time vs. Indoor Relative Temperature	0.000*	significant correlation
5.	Fan switch on time vs. Outdoor mean radiant temperature	0.044*	Significant correlation
6.	Fan switch on time vs. Outdoor Relative Humidity	0.289	No significant correlation
7.	Fan switch on time vs. Indoor mean Radiant Temperature	0.000*	Significant correlation
8.	Fan switch on Time vs. Indoor Relative Humidity	0.030*	Significant correlation
9.	How do you make yourself comfortable (Hot) vs. Outdoor mean radiant temperature	0.018*	Significant correlation
10.	How do you make yourself comfortable (Hot) vs. Outdoor Relative Humidity	0.487	No significant correlation
11	How do you make yourself comfortable (Hot) vs. Indoor mean Radiant Temperature	0.003*	Significant correlation
12	How do you make yourself comfortable (Hot) vs. Indoor Relative Humidity	0.195	No significant correlation
13.	How do you make yourself comfortable (Cold) conditionvs.Outdoor mean radiant temperature	0.275	No significant correlation
14.	How do you make yourself comfortable (Cold) condition vs. Outdoor Relative Humidity	0.903	No significant correlation
15.	How do you make yourself comfortable (Cold) condition vs. Indoor mean Radiant Temperature	0.137	No significant correlation
16.	How do you make yourself comfortable (Cold) condition vs. Indoor Relative Humidity	0.228	No significant correlation

4.5 Objective 4: OCCUPANTS' BEHAVIOURAL ACTIONS AND ENERGY CONSUMPTION: To examine the relationship between occupants' thermal behavioural actions and energy consumption. Data collections were obtained with semi-structured questionnaire by energy audit team personnel for subjective measurements. These were thermal comfort occupants' operational control time uses of openings and actions taken for required comfort during wet and dry seasons through thermal comfort adaptive questionnaires. Data analyses (Table 4.12) were done with Pearson product moment correlation (r) and Pearson rank correlation coefficient (Rho) test conducted on collected variables to establish behavioural action relationship and energy consumption.

TABLE 4.12 Relationships between Occupants' Behavioural Actions and Energy Consumption

S/N	TEST VARIABLES	P-VALUE	INFERENCES
1	Weekly energy consumption vs. Living room open window	0.000*	Significant relationship
2	Weekly energy consumption vs. fan switch on time	0.993	No significant relationship
3	Weekly energy consumption vs. How do you make yourself comfortable when you feel cold	0.000*	Significant relationship
4	Weekly energy consumption vs. How do you make yourself comfortable during hot and humid condition	0.001*	Significant relationship

4.6 Objective 5 ENERGY CONSUMPTION MODEL

To develop a model for predicting energy consumption of residential buildings with different design parameters in Lagos Metropolis, energy indicators data collected from objectives 1&2 that are numeric and non-numeric were used for the development of energy model. Stepwise regression analyses were carried out on collected data through the application of identified most important energy consumption predictors as parameters using the AIC (Akaike Information Criterion) that measures the suitability of a model. Thus, the one with the lowest

AIC is the best predictor variables. Fig.4.8. The AIC effect of the energy predictors in the model shows that seven variables in their order of importance can comfortably predict weekly energy consumption of the households in the study area.

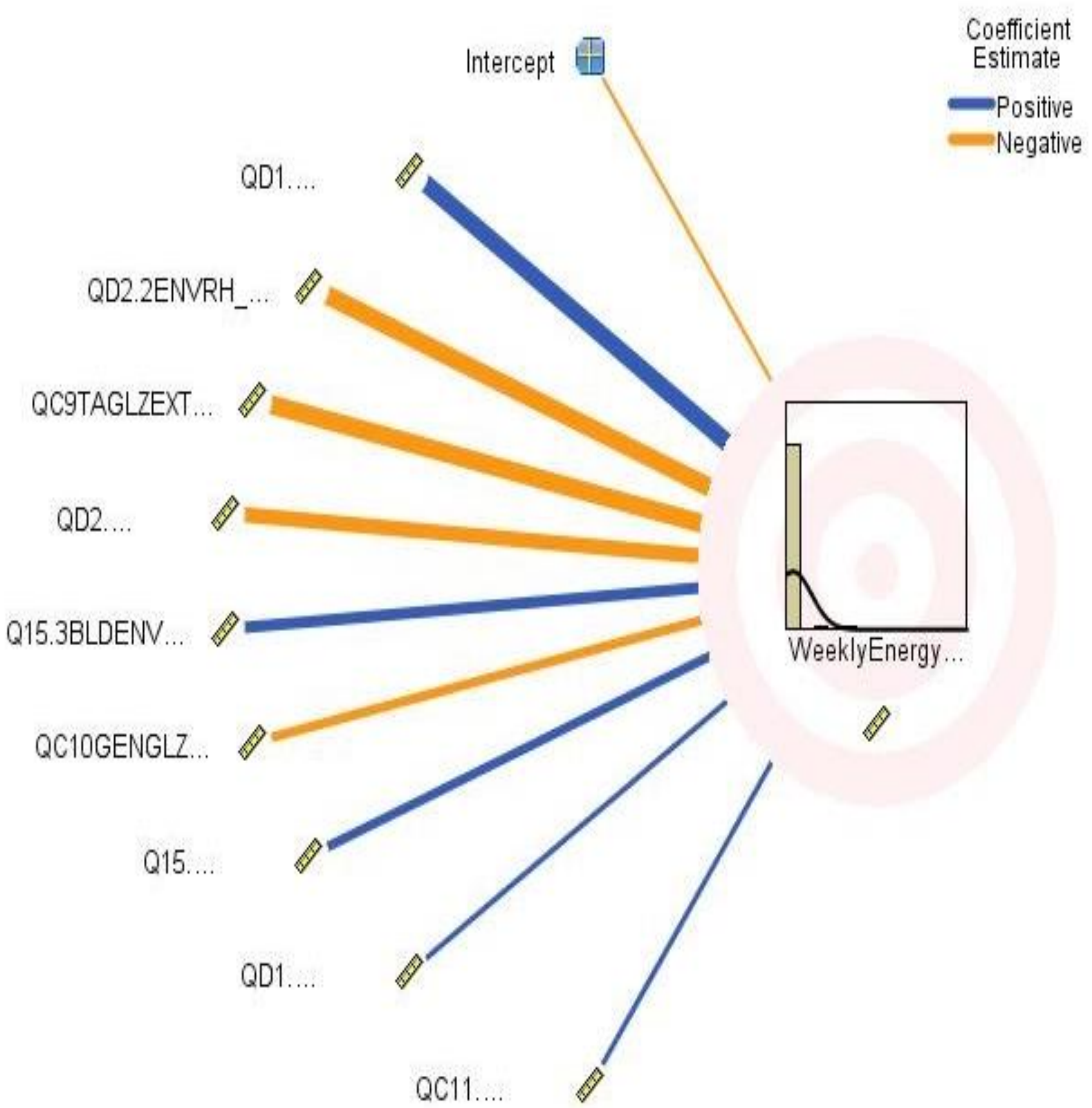


FIG. 4.8 Identified Variables of Energy Consumption.

These predictors include: Environmental Outdoor Relative Humidity (QD1.2), Environmental Indoor Relative Humidity (QD2.2), Total Glazed External Area (QC9), Indoor Temperature (QD2.1), Building Envelope Area (Q15.3), General Window Sizes (QC10) and Building Cool Floor Area (15.6).

TABLE 4.13: Model Building Summary: Target: Weekly Energy Consumption Target

		Step								
		1	2	3	4	5	6	7	8	9
Information Criterion		4,786.091	4,760.111	4,731.105	4,721.720	4,712.771	4,708.505	4,704.873	4,704.296	4,704.250
Effect	Q15.6BLDCLFLAR_transformed	✓	✓	✓	✓	✓	✓	✓	✓	✓
	QD1.2ENVOUTRH_transformed		✓	✓	✓	✓	✓	✓	✓	✓
	QD2.2ENVRH_transformed			✓	✓	✓	✓	✓	✓	✓
	QC9TAGLZEXT_transformed				✓	✓	✓	✓	✓	✓
	QD2.1ENVINDTEMP_transformed					✓	✓	✓	✓	✓
	QC10GENGLZSIZ_transformed						✓	✓	✓	✓
	Q15.3BLDENVLP_transformed							✓	✓	✓
	QD1.1ENVOUTTEMP_transformed								✓	✓
	QC11.1NOWDONE_transformed									✓

The model building method is Forward Stepwise using the Information Criterion.
A checkmark means the effect is in the model at this step.

TABLE 4.14: Coefficients Target: Weekly Energy Consumption Target

Model Term	Coefficient ►	Sig.	Importance
Intercept	-17.245	.915	
QD1.2ENVOUTRH_transformed	10.199	.000	0.476
QD2.2ENVRH_transformed	-3.760	.000	0.151
QC9TAGLZEXT_transformed	-7.455	.000	0.131
QD2.1ENVINDTEMP_transformed	-19.864	.001	0.084
Q15.3BLDENVLP_transformed	0.139	.009	0.053
QC10GENGLZSIZ_transformed	-59.923	.026	0.038
Q15.6BLDCLFLAR_transformed	0.241	.034	0.034
QD1.1ENVOUTTEMP_transformed	10.555	.142	0.016
QC11.1NOWDONE_transformed	8.235	.148	0.016

Thus, the one with the most mark has the most effect in the model. From the above Table, the following seven highlighted variables are found useful in the model: QD1.2, QD2.2, QC9, QD2.1, Q15.3, QC10, and Q15.6

Thus, the equation of the above model is expressed as:

$$\mathbf{Y}= \boldsymbol{-17.245 + 10.199X_1 - 3.760X_2 - 7.455X_3 - 19.865X_4 + 0.139X_5 - 59.923X_6 + 0.241X_7}$$

Where

Y=Weekly Energy Consumption

$$\boldsymbol{\beta_0 = Intercept}$$

Parameter Estimate for Outdoor relative Humidity==$\boldsymbol{X_1}$

Parameter Estimate for Indoor Relative Humidity=$\boldsymbol{X_2}$

Parameter Estimate for External Total Glazed Area=$\boldsymbol{X_3}$

Parameter Estimate for Indoor Temperature=$\boldsymbol{X_4}$

Parameter Estimate for Building Envelope Area=$\boldsymbol{X_5}$

Parameter Estimate for General Glazing Size=$\boldsymbol{X_6}$

Parameter Estimate for Building Cool Floor Area=$\boldsymbol{X_7}$

Thus, the most important parameter in the model is Environmental Outdoor Relative Humidity (QD1.2) which accounts for 47.6% of the explanatory variable. Furthermore, for the non-numeric variables, we used the Pearson Chi-square test to ascertain the relationship between variables. From this, the one with a relationship is considered as part of the variables that contribute to energy consumption. This has been shown in objective 1. In conclusion, in the first diagram above, FIG 4.8 the blue indicators signify the variables that have positive effect in the model, while those with yellow indicators signify the variables having a negative effect on the model.

TABLE 4.15: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.220[a]	.048	.046	253.42736
2	.336[b]	.113	.109	244.92020
3	.389[c]	.151	.145	239.86065
4	.415[d]	.172	.164	237.21270
5	.444[e]	.197	.188	233.87091
6	.454[f]	.206	.195	232.84933

The above table 4.15 is the stepwise regression of eight variables in which the first variable that entered the model was the indoor mean radiant temperature with an R^2 value of 0.048 and adjusted R^2 of 0.046. This means that only 4.8% of the weekly energy consumption was explained by the indoor mean radiant temperature. The second variable that was added in the next step regression was the Outdoor Relative Humidity with an adjusted R^2 of 0.109 and R^2 value of 0.113. Since we are dealing with more than one independent variable, more emphasis is laid on the adjusted R^2 since it considers the second variable in its calculation. Thus, 11.3 % of the weekly energy consumption was explained in the two independent variables (Indoor Mean Radiant Temperature, Outdoor Relative Humidity). The third step regression added the indoor relative humidity to the other two independent variables considered and the value of the adjusted R^2 increased to 0.145 which implies that 14.5% of the weekly energy consumption was explained in the three independent variables (Indoor Mean Radiant Temperature, Outdoor Relative Humidity and Indoor Relative Humidity). The fourth step regression included the resident cooled floor area internal dimension with an adjusted R^2 value of 0.164 which means that 16.4% of the weekly energy consumption was explained in the four independent variables (Indoor Mean Radiant Temperature, Outdoor Relative Humidity, Indoor Relative Humidity, Residential cooled floor area internal dimension). The fifth step regression added the total area glazed of external walls and windows with an adjusted R^2 value of 0.188 which implies that 18.8% of the weekly energy consumption was explained in the five variables entered (Indoor Mean Radiant Temperature, Outdoor Relative Humidity, Indoor Relative Humidity, Residential cooled floor area internal dimension and Total area glazed of external doors and window). Then lastly, the sixth step regression accounted for an adjusted R^2 value of 0.195 which accounted for 19.5% of the weekly energy consumption explained in the six variables entered (Indoor Mean Radiant Temperature, Outdoor Relative Humidity, Indoor Relative Humidity , Residential cooled floor area internal dimension, Total area glazed of external doors and windows, Building envelop area external dimension).

4.6.1 HYPOTHESIS ONE

4.6.1.1 H_0 Null Hypothesis 1.1: There is no significant relationship between residential building characteristics and energy consumption in Lagos metropolis.

H_1Alternative Hypothesis 1.1: There is significant relationship between residential building characteristics and energy consumption in Lagos metropolis.

The result shows that at $\propto$ = 0.05 level of significance, the following residential building characteristics have significant relationship with energy consumption: Building Location, Building orientation, Main type of ventilation, Building roof type, Total area glazed of eternal doors and windows, Total size of glazed windows, Numbers and Areas of windows in North East, South West, South East and North West, Roof eave, Building Circumference, Building Length, Building Envelope, Internal Building Total area, Internal cool floor area and Building Volume. These have been shown in the results obtained from Table 4.1.Thus the alternative hypothesis is accepted.

4.6.2 HYPOTHESIS TWO

4.6.2.1 H_0 Null Hypothesis 2.1: There is no significant relationship between environmental factors and energy consumption in residential buildings in Lagos metropolis.

H_1Alternative Hypothesis 2.1: There is significant relationship between environmental factors and energy consumption in residential buildings in Lagos metropolis.

The result shows that at $\propto$ = 0.05 level of significance, the following environmental factors have significant relationship with energy consumption: Outdoor relative humidity and Indoor mean radian Temperature. Hence, the alternative hypothesis is accepted. This was shown in Table 4.2.

4.6.3 HYPOTHESIS THREE

4.6.3.1 H_0 Null Hypothesis 3.1: There is no relationship between weekly energy consumption and actions taken to ensure indoor comfort iN residential building in Lagos metropolis.

H_1Alternative Hypothesis 3.1: There is a relationship between weekly energy consumption and actions taken to ensure indoor comfort in residential building Lagos metropolis.

The result shows that at $\propto = 0.05$ level of significance, the following occupant's actions have significant relationship with energy consumption: Window and door opening time, Fan and Air conditioner switch on time. This has been shown in Table 4.12 as explained by the respondent use of windows in their living rooms during hot and wet conditions in response to comfort condition. Therefore the alternative hypothesis is accepted.

4.6.4 HYPOTHESIS FOUR

4.6.4.1 H_0 Null Hypothesis 4.1: There is no significant relationship between occupants behavioural actions and energy consumption in residential buildings in Lagos metropolis.

H_1Alternative Hypothesis 3.1: There is significant relationship between occupant's behavioural actions and energy consumption in residential buildings Lagos metropolis.

The result shows that at $\propto = 0.05$ level of significance, the following occupants' behavioural actions have significant relationship with energy consumption: Opening and closing of windows, Get more cold drink, take shower often, Turn up some light fixtures. Table 4.4 has indicated this. Hence the alternative hypothesis is accepted.

CHAPTER FIVE:

5.1 DISCUSSION AND SUMMARY OF FINDINGS.

This chapter summarises and discusses the results of the findings of the study, following its stated objectives. This is done through the discussion of the established relationships and contributions, thereby making deductions from the determination and control of energy consumption through architectural design parameters, environmental indicators and human behavioural actions.

5.1.1 BUILDING CHARACTERISTICS IN THE STUDY AREA

The explanation of the building characteristics in the study area with reference to energy consumption, as analysed by descriptive statistics, shows that buildings with adequate natural ventilation constitute 47.2% of the population of the sampled households. In the same way, mixed mode buildings represent 44.9% of selected buildings while mechanically ventilated building account for 6.5% of the population (Table 4.2). This shows a ranking of energy intensive buildings constituting the lowest population of sampled buildings. This is followed by energy optimized buildings as naturally ventilated households were in majority. This is likely due to building age and economic reasons which are beyond the scope of this research.

However the mean age value of sampled buildings was found as 21.7 years. This period signifies the beginning of uncontrollable rapid population growth in Lagos. Most sampled buildings were located within the urban area of Lagos which constitutes 76% of the population, with only neighbourhood population of 21% of households sampled. This sampling supported the location for high population dense area of the city with thermally insensitive and energy intensive building concentration (See Table 4.2).

Also, most of the buildings were with poor orientation which does not aid energy conservation and efficiency attainment. 35.3% has a north-south orientation that exposes larger envelope area to solar radiation. This consequently is responsible for internal heat generation among households, resulting in thermal comfort problem that necessitated the acquisition and use of air conditioners in most of the different categories of households. Only 29.3% of the buildings have East- West orientation that can aid energy efficient consumption. In this category, only smaller surface areas of the building are exposed to severe solar radiation. This is as a result of the poor layout schemes from the planning stage and inability of physical control policy instrument to address issues involving energy use. (See Table 4.2) This is confirmed by the significant effects found at 0 .001 Pearson Chi-Square level, and supported statistically with Linear by Linear association at 0 .002 level. The location of the buildings also show a Pearson chi-square significant at 0 .000 level. This is explained by urban area location of the sampled population. In essence, this supported the fact that mostly high population density locations have significant effect on energy consumption among households in Lagos. (See Table 4.6)

The building materials for construction, with respect to roofing type result shows the Pearson chi-square been significant to the amount of energy households consume at 0.001 levels, with a Linear to Linear association at .000 level of significant. This is also found to be true for the choice of ceiling material used at Pearson chi-square significant level of 0 .000, which also has a significant linear to linear relationship. However, there were no significant relationships between wall material and house types with energy consumption. This implies that the type of building does not have any effect on energy use. But the choices of wall material are adequate and thermally sensitive to energy consumption in the climatic area of Lagos. (See Table 4.6)

The parametric variables relationship of building characteristics and energy consumption in Lagos reflected that among the building envelope variables, building’s volume, cooling area of buildings and the amount of external glazed areas were significant to energy consumption. While their Pearson correlations are positive, only external glazing inversely correlated. This means that their opening to floor area ratio are not adequate.

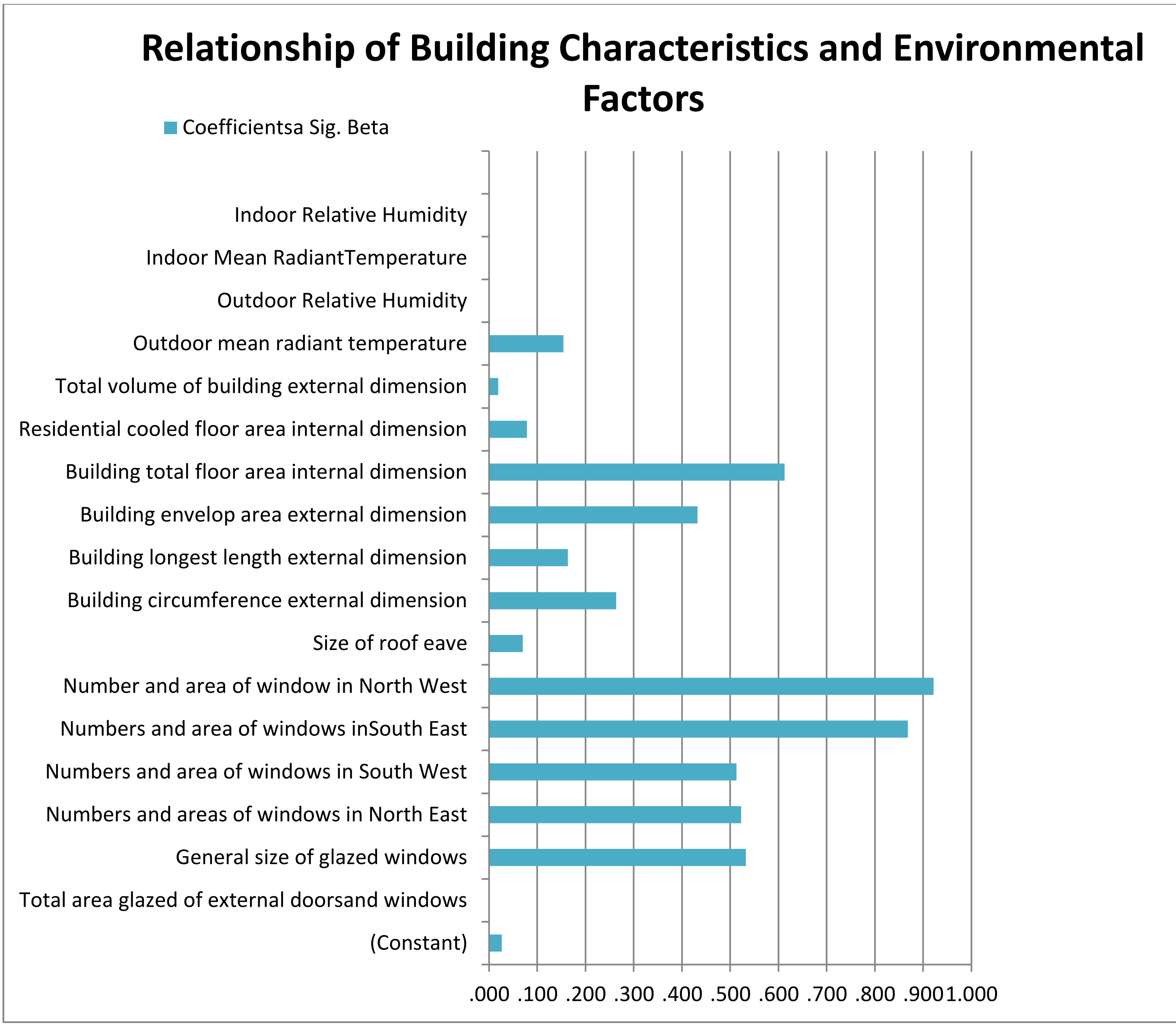


FIG.5.1 Relationship between Building Characteristics and Environmental factors

The rectangular building form represents the bulk of the sampled population with 94.5%. Although researchers do not agree to a specific building form that optimize energy consumption, but form manipulation to effect good shading devices from solar radiation constitute a savings to energy consumption. This can only be made possible through adequate plot sizes and shapes which is not the case in the study area. Interestingly, the shapes of the plots and planning regulations influenced the evolution of rectangular form of most buildings. (See Fig. 4.1).

This was found responsible for the buildings length mean value of 23.4m, with a circumference mean value of 72.5m that definitely impacted negatively on energy consumption, due to their large exposure to solar radiation. In essence, rectangular and slim buildings that may encourage mechanical ventilation were predominant among the building populations due to the plot layout shape and sizes restriction in the study area.

The building envelopes that generally shield occupants from external harsh environment has a mean value of 485.9m2, while hollow sand Crete blocks constitute the highest proportion of the wall materials with 89.9%. Solid brick constituted only 8.3%, while concrete walling represented only 1.6% of the sampled buildings (See Table 4.3). These materials used were largely responsible and encourage night cool in the study population.

This explains the thermal behavioural actions of 62.8% window opening in the morning and 41.9% fan switch on time in the evening to encourage air movement in most naturally ventilated households that constitute majority of the sampled population. This makes most of the buildings habitable, despite the non-availability of energy supply with a daily supply mean value of 2.33 hours that encourages night occupation in most households.

The opening in most of the sampled buildings were fixed with single glazed windows which constitute 96.8% and does not encourage energy saving potential like the double glazing windows that accounted for only 1.8%. Windows were located on all sides of the buildings with a mean range of 3.65m^2 to 3.24m^2, and a general window glazing mean of 2.48m^2 and total glazed average of 15.19m^2. This is vital and responsible for the thermally insensitivity of residential designs in Lagos that impact negatively on energy consumption when expressed as a ratio of opening to floor area of energy efficient buildings. Spearson correlation confirms a positive significant relationship existing between building envelope, cool floor area, volume of building and energy consumption, (See Table 5.1).

The roof characteristics of the building population showed that gable roof constitutes 61.3%, while hip roof only accounted for 21.2% of the population. 15.9% of the roofs were flat, while Asbestos roofing materials were used by 47.2% of the sampled houses, 23.5% used Aluminium sheets. Similarly, corrugated iron roofing sheets constitute 26% of the population, while concrete roof constitutes 1.2% only. These findings, strongly supported savings in energy consumption of the roof choices in the study area, but needed to be backed up with correct specification of absorsivity values, according to Olufowobi (2009) in Table 2.1. The selected building roof eaves show that 75.3% of the buildings population were within 0.90m and below, as eaves up to 1.5m represents 20.7% of the population. 1.4% does not have any roof eave. Roofs are generally responsible for 35% building characteristics (through) absorsivity of heat into the indoor environment. The roof eave that constitutes the highest percentage falls short of adequacy to provide shading of the envelopes wall and window openings for reduction of radiant heat and subsequent indoor passive cooling which can lead to energy savings in the study area. This effect on energy consumption is confirmed in the Pearson chi-square significant and Linear by Linear association at .000 significant levels as reflected in Table 5.1.

Table 5.1: Summary of effect of Building Characteristics on Energy Consumption by Pearson Chi-Square

Building Characteristics	Significant	Linear by Linear Association
Building Location	0.000	0.431
Orientation	0.001	0.002
Ceiling Material	0.000	0.000
Roof Type	0.000	0.000
Building Envelope	**Significant**	**Pearson Correlation**
Building length	0.008	12.9%
Building Cool Area	0.000	19.9%
Building Volume	0.001	16.3%
Building External Glazed Area	0.003	-14.3%

Table 5.2: Descriptive Statistics of Building Characteristics

	Building Variables	Sampled	Percentage (%)
Building Orientation	North-South	153	35.3
	East-West	127	29.3
	South East/North East	80	18.4
	North East/South West	74	17.1
Building Form	Triangle	7	1.6
	Rectangle	410	94.5
	Square	16	3.7
	Polygon	1	0.2

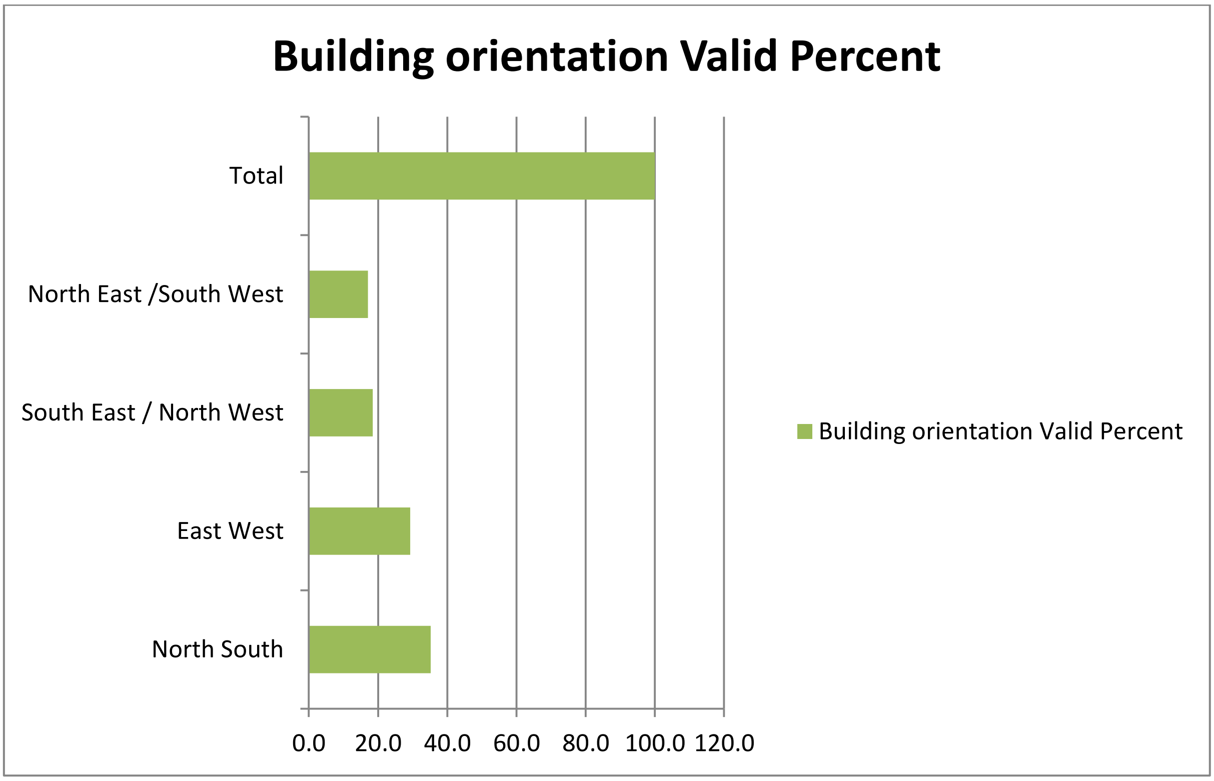


FIG.5.2 Descriptive Percentage of Building Orientation Characteristics

Table 5.3: Building Envelope Materials

	Variables	Sampled	Percentage (%)
Wall	Brickwall	36	8.3
	Hollow Sandcrete Block	390	89.9
	Reinforced Concrete	7	1.6
Window Types			
	Single Glazing	420	96.8
	Double Glazing	8	1.8
Roof			
	Asbestors	205	47.2
	Aluminium	102	23.5
	Iron Sheet	113	26.0
	Reinforce Slab	5	1.2
	Others	9	2.1
Roof Types			
	Flat	69	15.9
	Gable	266	61.3
	Hip	92	21.2
	Others	7	1.6

The percentage population of the study area building mode of 47.2% is actually responsible for thermally insensitivity characteristic of the buildings. Although closely followed by mixed-mode buildings that encourage energy savings, but the dominant population still reflect that have not realised the need to adopt tropical bioclimatic principles in Lagos which is important to ensuring that residential buildings are energy responsive.

Table 5.4: Residential Building Mode

	Building Variables	Sampled	Percentage (%)
Building Mode	Natural ventilation	205	47.2
	Controlled Ventilation	5	1.2
	Mechanical Ventilation	28	6.5
	Balanced Ventilation	1	0.2
	Mixed-mode	195	44.9

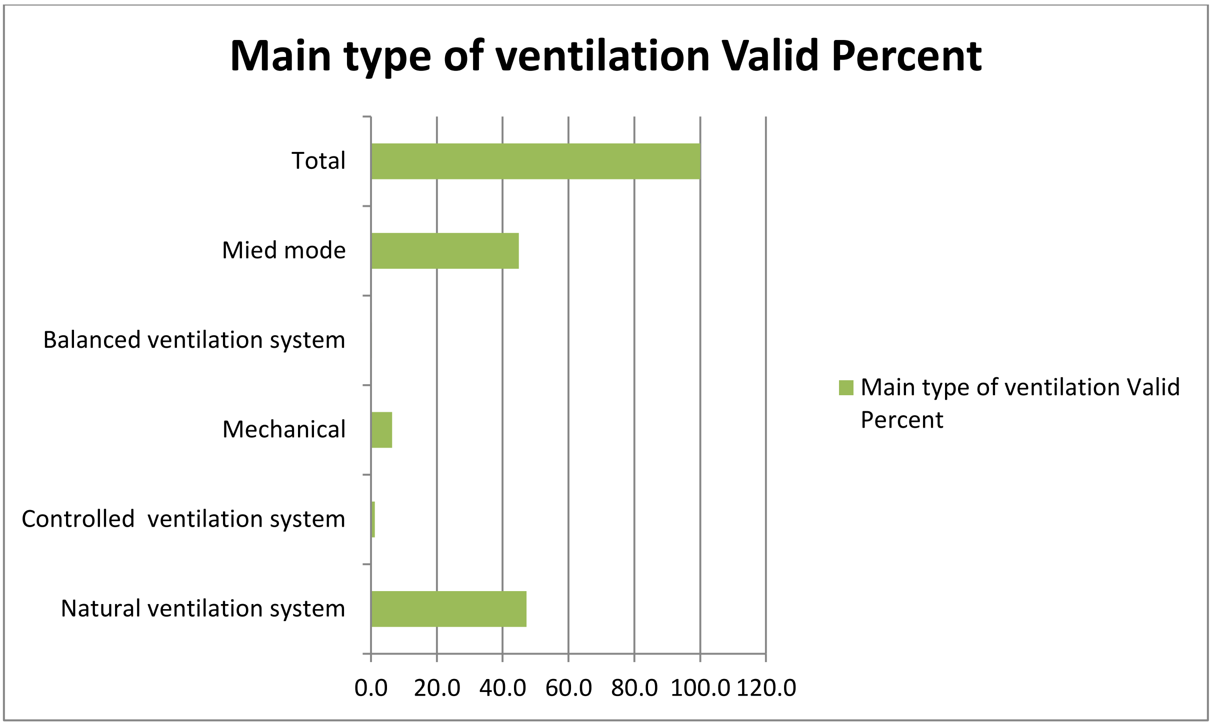


FIG.5.3 Residential main types of Ventilation

5.1.2 ENERGY USE INDICATORS

The bivariate analysis test takes each determining factor of design, environmental and occupant's behavioural actions variables in turns to establish their correlation coefficient for parametric and non-parametric level of significance to energy consumption in the study area.

5.1.2.1 BUILDING DESIGN FACTOR INDICATORS

The significant contributing factor of the building orientation in the study population can be explained by 28.8% of the energy consumed, as shown in table 5.5. This ranked first among the building design factors, signifying its importance to energy consumption, as most of the sampled buildings in the study area were poorly orientated in north-south. But the best orientation for energy efficient building is an east-west orientation. The north-south orientation increases the internal heat absorption of the building envelopes. The resultant effect is poor building thermal condition, as identified by Adebamowo (2006).

Building form is inversely correlated to energy consumption of the study area. The reason is that only rectangular buildings were dominants. This is explained by the available restrictive nature of layout plot, which does not encourage form exploration of large surfaces but compact ones that do not favour ventilation, Hackerhnect (1993). But on the other hand, compact form encourages the use of air condition Givoni (1980). This explains the positive correlation of both building external envelopes contribution of 28.7% of consumption in the study area. The external wall material choice of sandcrete block negatively correlated to energy consumption. Its dominance does not encourage good energy savings for reason of thermal conductivity as it releases heat into the internal building area at the time buildings were mostly occupied. This necessitates high energy consumption for cooling effect, depending on the building mode of the household.

The choice of roofing design and eave overhang also positively correlated with energy consumption which can only be explained by a correlation coefficient of 38.1%. The relationship, at a significant level of 0.001, shows that depending on the building roof design and overhang projection, quite a lot of energy consumed in the study area can be conserved. But because the roof eaves projection are grossly inadequate, as dominated by less than one metre projections, building external walls and openings are subjected to radiant heat in most cases. Again, this is the case in a poorly orientated built environment that does not make provision for balance in landscape planning of soft and hard scapes of building locations. The relationship existing between households energy consumption, general window size and total glazed area of building is explained as inversely proportional to building design characteristics, as shown in FIGS. (4.1 & 4.4). This reflects a negative impact on the household’s energy consumption. In external building envelope area and total cooled internal building area, there is a directly proportional relationship that is positive. This however, signifies that the more possible control design has on constituent of general window sizes and total glass area of building through building's envelope characteristics, the better control of energy consumption intensity of the households in the study area. See FIGS. (4.2 & 4.3).

In summary, the positive correlation coefficient of building design variables and energy consumption determination in the study area is significantly responsible for the determination of the energy consumption of households' occupants in Lagos (Table 4.9).

Table 5.5: Building Design Factors

Variables	**Correlation Coefficient**	**Significance Level**
Building Orientation	28.6%	0.000
Building Form	-0.2%	0.000
Building External Dimension	17.3%	0.008
Building envelope Area	11.4%	0.018
Roof Type	21.1%	0.001
Size of Roof Eave	16.0%	0.001
Wall material	-11.1%	0.021

5.1.2.2 ENVIRONMENTAL FACTOR INDICATORS

The environmental factor indicator in the determination of energy consumption, as analysed, shows both positive and negative correlation coefficient at different level of significance. The indoor households' temperature correlated negatively as explained to the level of -21.8% at 0.00 significant levels. This means that any change in indoor temperature will result in an increase of up to 21.8% energy consumption consequences of the households in the study area. This is mostly determined by the absorptivity of the building envelopes material choices. When this is related to the mean value of indoor temperature of 27.92^0c and the increase of outdoor 2^0c (NEM) as recorded in 2015, its shows a significant effect on energy consumption among households. The resultant effect of inadequate supply trend is dependent on alternative fossil based energy supply from generators by 87% of the population. The possible level of carbon emission that can impact negatively on environmental condition cannot be imagined, although this is beyond the scope covered by this study.

The outdoor relative humidity, on the other hand, positively correlates with the energy consumption with a coefficient of 15.6% at 0.001 level of significance. The contribution of relative humidity to energy consumption can be explained by just 15.6% coefficient correlation. This means a dehumidification requirement of the households to energy consumption during the survey period (Table 4.10). To this end, air-conditioning energy consumption will remain on the increase, even as outdoor air gets humidified. Important as well, air movement rate to improve indoor air quality of the naturally ventilated building mode dominated in Lagos will be at comfort jeopardy. Hence, more buildings will require air condition installation that is energy intensive and accounts for up to 60% of energy consumption in tropical buildings, Sangowawa and Adebamowo, (2010). This also conforms to the International Energy Agency projection that up to 72% increase in air conditioning energy demand between 2000-2100 is to be in Asia and Africa. This is significant, given that Nigeria has the highest population in Africa. The environmental variables of outdoor relative humidity show a relationship that is directly proportional to energy consumption, as indicated in FIG.3.5 where the indoor relative humidity is signified by an inversely proportional relationship to energy consumption. This explain why the prevailing outdoor relative humidity control through application of appropriate tropical bioclimatic principle of mixed mode for air movement when necessitated by design is highly recommended for the study area. This is understandable since indoor relative humidity is dependent on outdoor relative humidity, air movement and ventilation mode of households.

At the same time, the relationship in indoor mean temperature is inversely proportional to energy consumption, meaning that the lower the indoor temperature of households, the higher the energy consumption and vice versa, as illustrated in FIG. 4.7. This explains why the need for heat dissipation is highly essential to households in optimizing energy consumption through appropriate ventilation mode for the study area known to be warm and humid.

In summary, the contribution of environmental factor in the determination of energy consumption in the study area is found to be significant. This is explained by the positive correlation coefficient of 15% from outdoor humidity responsible for actions taken by the occupants in the households.

Table 5.6: Relationship between Environmental Factors and Energy Consumption

Variables	Correlation Coefficient	Significance Level
Indoor Temperature	-21.8%	000
Indoor Relative Humidity	-	
Outdoor Temperature	-	
Outdoor relative Humidity	15.6%	001

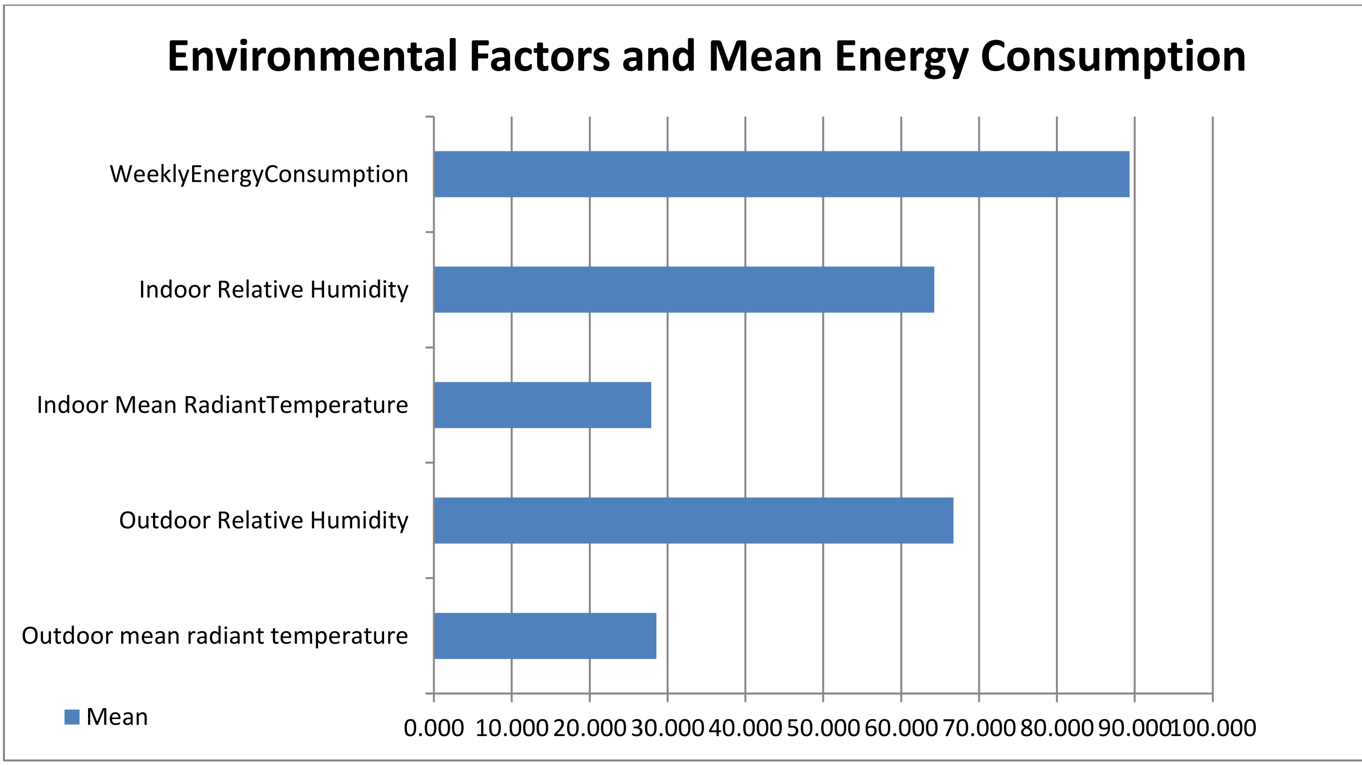


FIG.5.4 Environmental determinant factors of Energy consumption

5.1.2.3 OCCUPANTS' THERMAL BEHAVIOURAL FACTORS

Occupant's thermal behavioural action in the determination of energy consumption is explained by the use of those building control characteristics and the responses of occupants to indoor and outdoor environmental conditions. This involves their responses to indoor conditions for hot humid environment and the cold condition in the use of both passive and active energy driven household conditions.

Factors such as hot humid indoor condition, window opening operation, fan switch on time and daily hours of electricity supply correlate positively at different degrees. The availability of air conditioners, occupancy rate and cold conditions indoor environment behaviour correlate negatively with energy consumption. The correlation coefficients of 12.7% of daily hours of energy availability and significant level of 0.008 explained by the ten out of twenty four hours in day supply prevalence in the study area. This explains the behavioural action of sole dependence on alternative source of fossil supply means. It further worsens indoor air quality supply from air and noise pollution hence explanation of prevalent actions of none window openings.

The correlation coefficient actions involving the use of fan is a vital statement with respect to the viability of mixed mode buildings adoption. This factor is a more realistic option in tropical buildings for energy consumption savings because it shows almost equal and opposite relationship of equal positive and negative correlation coefficient values as significant. This means that only when conditions are at extreme, air conditions should be in use, therefore justifying the efficacy of bioclimatic design principles as more applicable to Lagos environmental conditions as against mechanical mode.

Occupant's behavioural action is therefore controlled by factors centring on energy hour availability, the optimal use of both building design control characteristic, and the prevalent indoor condition at most time. This, to a greater extent, significantly determines household's energy consumption rate in the study area, depending on the prevailing environmental condition and the building mode (Table 4.12).

Table 5.7: Occupant's Behaviour

Variables	Correlation Coefficient	Significance Level
No. Of Occupant	-10%	0.037
Time of Occupation	-	-
Daily Hour of Electricity Supply	12.7%	0.008
Hot and Humid Comfort Actions	15.2%	0.002
Cold Condition Comfort Action	-18.4%	0.000
Window Opening Time	32.5%	0.000
Fan Switch on	22.6%	0.000
Air Condition Installation	-22.8%	0.000

However, Pearson chi-square test shows that a significant effect on energy consumption by outdoor RH relative humidity, a linear by linear relationship exists. This is also true of the indoor radian temperature and indoor relative humidity. However, this is not so with the case in Table (4.10) outdoor temperature.

5.1.3 ENVIRONMENTAL VARIABLES IMPACTS ON OCCUPANTS' BEHAVIOURAL ACTIONS

This bivariate test uses the environment variables of indoor and outdoor temperature and relative humidity to determine the occupant's thermal behavioural responses and actions in the use of the available passive and active controls towards energy use in the households. The attempt is to explain their reactions to thermal comfort situation in households as indicated by their actions to energy consumption. This is made possible through the correlation of their relationship with the prevalent indoor environmental condition.

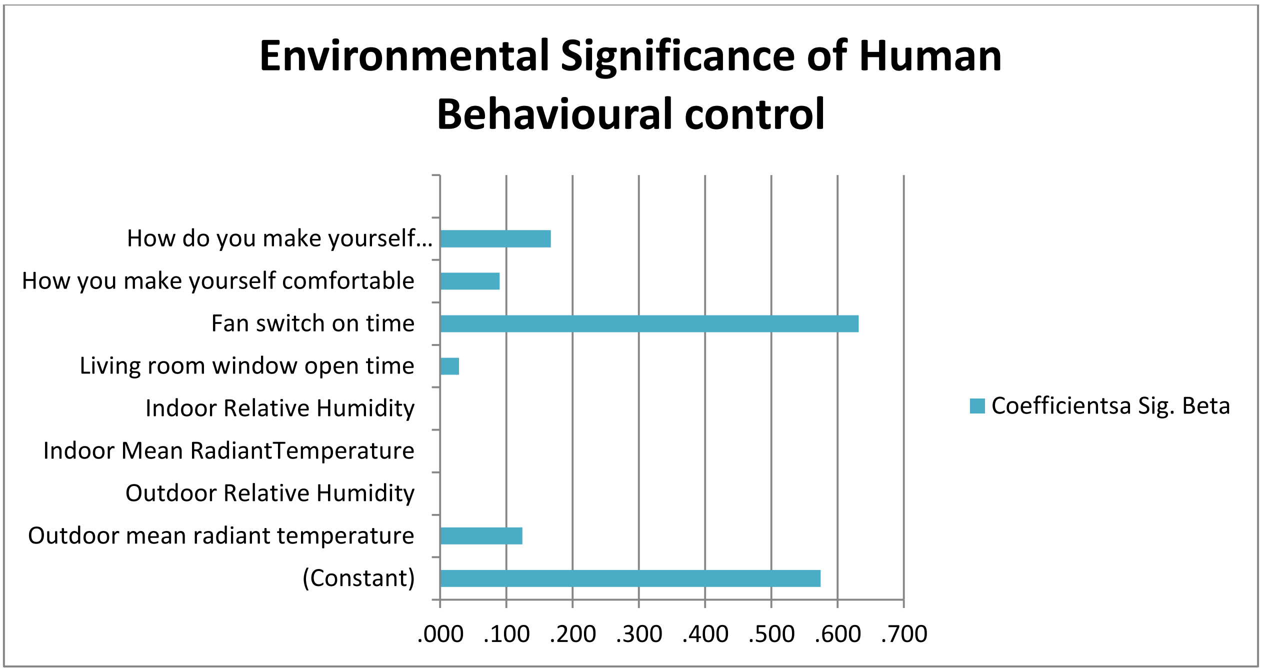


FIG.5.5 Environmental effect on occupant's behavioral use of building control characteristics

The passive action of the occupant towards energy consumption that could be taken is window opening operation which correlates positively to energy use. However, it inversely correlates with both indoor and outdoor temperature and relative humidity. These shows that when windows are used at adversely prevalent environmental conditions, energy savings results. This is encouraged by natural and mixed-mode buildings. However, use of fan, on the other hand, also correlates positively with energy consumption. But it inversely correlates with indoor and outdoor temperature and relative humidity. This suggests that there is possibility of energy use in the households when occupants take action.

The inversely significant high correlation of air conditioner used in the result can explain its impact on energy consumption been intensive. This is responsible for driving consumption in the mechanical building and explains as well the positive correlation of hot humid conditions actions of the occupants. Moreover, this is the situation during thermally uncomfortable periods of indoor and outdoor temperature with an inverse correlation to indoor conditional period of occupants' actions.

The cold indoor condition period behaviour of household that negatively correlates with consumption explains the passive actions taken by occupants. This results in energy saving which is further confirmed by the positive correlation with indoor humidity at a slightly higher level of significance. The passive energy use actions of occupants in use of window control is significant and positively correlates with when a fan is switch on and hot and humid time. Likewise, it negatively correlates with and significant to indoor and outdoor temperature and humidity at the same time. This shows that savings in energy consumption are made possible through the adequate timely use of this control for comfort without reliance on active means that impact on energy consumption. This is further explained by the higher significant relationship between outdoor and indoor relative humidity and the indoor and outdoor mean temperatures. While the negative correlations that are significant at 98% confident level of both indoor mean temperature and outdoor relative humidity are responsible for actions of occupants during hot and humid conditions. Hence, both indoor temperature and outdoor relative humidity are enough to drive occupants' responses to active energy use at all times.

Table 5.8: Environmental Variables Impact On Occupants' Behaviour

Occupants Behavioural Control	**Energy Consumption**		**INDOOR**				**OUTDOOR**			
			Temperature		**Relative Humidity**		**Temperature**		**Relative Humidity**	
	Corr.	**Sig.**	**Corr.**	**Sig.**	**Corr.**	**Sig.**	**Corr.**	**Sign.**	**Corr.**	**Sign.**
Window Operation	17.3%	000	-31.2%	000	-37.8%	000	-16.1%	001	-36.6%	000
Fan Switch Time	15.3%	000	-14.4%	000	-8.0%	000	-9.2%	011	-4.2%	042
Hot and Humid Condition	9.9%	016	-10.4%	004	-	-	-8.6%	018	-	-
Cold Condition	-10.6%	029	-	-	9.5%	049	-	-	-	-

5.1.4 RELATIONSHIP BETWEEN BUILDING CHARACTERISTICS CONTROL USES AND DETERMINATION OF ENERGY CONSUMPTION

This involves a bivariate test of identified building controls characteristics in different building modes on occupants' behavioural use and their impact in determining energy consumption. This is explained by the coefficient of correlations between different building characteristic and occupants' actions with their level of significance.

This action of the occupant's behaviour explains the vital control that design has in the control of energy consumption. It is shown here that the building characteristic, to a great extent, is responsible for driving energy use in the household. Building orientation characteristic alone is responsible for the highest correlation of energy. This is influenced by the positive highest correlation of fan use action of the occupant. In turn, this corresponds to the uncomfortable indoor period of hot and humid condition of the occupants and the availability of air conditioners in the households.

The house building mode, on the other hand, ranks next to this with positive correlation coefficient with the design control and possible occupants' actions of window operation, fan use at the time of indoor uncomfortable period of hot and humid condition.

The external wall material choice however inversely correlates with window opening actions and, by extension, with energy consumption. This shows that the choice of wall material possibly brought about energy saving potential, as it also does with window operation. Window general size, however, shows no correlation to its operation, it brought about energy saving potential in active energy, as reflected in the negative correlation of the fan use operation and, consequently, energy consumption. The choice of roof type positively correlates with energy consumption, while negatively with both hot humid and cold condition of the household. This explains its roles to energy saving during both conditions, as the choice of gable and hip types dominated the building sample population in the study area.

The existence of roof eaves overhangs correlates positively with window operation explaining the potential possibility existing between both in respects to shading provision. This indicates its potentiality, as it correlates positively with energy consumption and significant to it. The possible explanation here is the shading factor of the roof to the building envelopes in general in the determination of occupant’s use of available control towards energy consumption.

In summary, the potential energy saving available to energy consumption largely depends on the appropriate application and use of the building characteristic available to occupants. This is to control the external environmental factor and indoor environmental comfort to the benefit of the occupants. The control of the factors in the environment can be realized through relevant building design mechanisms to ensure the control of effective energy consumption.

Table 5.9: RELATIONSHIP BETWEEN BUILDING CHARACTERISTICS AND BEHAVIOURAL ACTIONS ON ENERGY USE

Building Characteristics	Window Operation		Fan Switch		Hot & Humid Condition		Cold Condition		Energy Consumption	
	Corr.	Sig.	Corr.	Sig.	Corr.	Sig.	Corr.	Sig.	Corr.	Sig.
Building Orientation	28.5%	000	14.7%	002	11.2%	020	-	-	25.3%	000
Building Form	-	-	-	-	12.8%	008	12.8	008	-	-
Wall Material	-11.6%	016	-	-	-	-	-	-	-9.7%	030
Window Size	-	-	-13.3%	001	-11.0%	022	-11%	022	-29.9%	000
Roof Type					-17.3%	000	-17.3%	000	20.7%	000
Eave Size	19.1%	000			-	-	-	-	9.2%	038
Building Mode	12.7%	008	11.5%	007	39%	000	-	-	17.1%	000

The relationship of building characteristic control on occupants' behaviour in their uses is further explained by the actions of window and fan switch on time in control of the indoor climatic conditions of hot humid and cold actions, as further confirmed by chi-square test result in (Table 5.10).

Building orientation, general size of window, roof eave sizes, area of building envelopes, circumference and length of building are found to positively correlate with and significant to the occupants' behavioural actions. This implies that their effective and correct applications during design could positively control occupants' uses and behaviours towards energy consumption among the households. This is also true for occupants' behavioural uses of controls during hot and humid internal conditions for building orientation, building form, general window sizes, roof types, eave sizes and building circumference at most time due to the prevailing environmental conditions. This also explains why occupants result to window closure habit. On the other hand, the inverse or negative correlations existing between building location, occupancy rate, wall material and external window area are significant at 95% confident level. This explains the crowdy nature of the residencies. With respect to prevailing density in Lagos, households' high occupations, inadequate window sizes that do not relate to good opening to floor ratios can discourage efficient energy utilization. This is responsible for fan switch on time in households as effective natural ventilation has been jeopardised.

In summarily, this can be explained from Tables 5.9 & 5.10. What is revealed is that the effect of relationship existing between building characteristics is significant to available passive and active operational control of the building design characteristics that directly influence the determination of the energy consumption. This is even more significant when it is related to the prevailing internal environmental condition during hot humid and cold periods. To a large extent, this signals a reaction of occupants to the thermal insensitive design prevalent in Lagos, with the environment in the attainment of their required comfort conditions.

Table 5.10: EFFECTS OF BUILDING CHARACTERISTICS ON OCCUPANT'S BEHAVIOUR IN DETERMINING ENERGY USE.

Building Characteristics	Occupants Behaviour	Pearson Chi-Square	
		Significant	**Linear by Linear Association**
Building Location	Fan Switch on time	000	000
		006	.138
Building Orientation	Living room window Operation	000	.000
	Fan Switch on time	001	.017
	How you make yourself comfortable	.100	.020
	Cold condition	.410	.001
Building Form	Hot Humid condition	.109	.008
	Cold condition	.016	.008
Ceiling material	Living Room opening time	000	000
	Fan Switch on time	002	.415
	Hot Humid condition	.202	.044
Roof Eave	Living Room opening time	.000	000
	Fan Switch on time	.049	.789
General size of windows	Living Room opening time	000	.952
	Fan Switch on time	000	.610
	Hot Humid condition	000	.268
	Cold condition	.009	.023
North-East window	Living Room window	000	.009
	Fan Switch on time	.037	.004
	Hot Humid condition	.000	.318
South-West window	Living Room window	.000	.574
	Fan switch on time	.315	.083
	Hot Humid condition	000	.214

South-East window	Living Room window	.000	.282
	Fan Switch on time	.101	.021
	Hot Humid condition	.000	.153
North-West window	Living Room window	.000	.000
	Fan Switch on time	.046	.045
	Hot Humid condition	.000	.148
	Cold condition	000	.234
Main ventilation mode	Living Room	0.000	.004
	Fan Switch on time	.000	.004
	Hot Humid condition	.000	0.000
	Cold condition	.306	.606
Roof type	Living Room	.000	.212
	Fan Switch on time	0.10	.837
	Hot Humid condition	.034	.824
	Cold condition	.007	.000

5.1.5 ENERGY CONSUMPTION MODEL

It is one of the considerations of this study to develop a model for the application of energy consumption parameters towards energy efficient building design within the Lagos metropolis. This is done through the application of the model building method of forward stepwise regression using information criterion. What is described in this is the effect of the predictor variables in the model using the AIC (Akaike Information Criterion) that measures the suitability of a model. Thus, the one with the lowest AIC is the best of predictor variables. These data were transformed and used in the model. As indicated, the one with the most mark has the most effect in the model. (See Table 4.5).

The AIC effect of the energy predictors in the model shows that seven variables in their order of importance can effortlessly predict weekly energy consumption of the households. These predictors include:

1) Environmental Outdoor Relative Humidity
2) Total Glazed External area
3) Environmental Indoor Temperature
4) Building envelope area
5) General glazing sizes
6) Building Cooled Floor Area
7) Environmental indoor Relative Humidity

These predictors constitute variables that have both positive and negative correlations with energy consumption. This is significant also to energy use and of households in the study area. Their percentage of importance shows their contributory level to the amount of energy consumption, as shown in Tables 4.13 & 4.14.

The model equation is:

WEEKLY ENERGY CONSUMPTION = INTERCEPT + 10.199 (OUTDOOR RH) – 3.760 (INDOOR RH) - 7.455 (ETERNAL GLAZED AREA) – 19.864 (INDOOR TEMP) + 0.139 (BLDG. ENVELOPE AREA) – 59.923 (GEN. WINDOW SIZE) +0.241 (BLDG. COOL FLOOR AREA)

The implication of the above is that the larger household energy consumption depends on the outdoor relative humidity which constitutes 47.6% of the parameter that determines energy use. This is nature driven as explained by the prevailing humid condition of the study area. Mostly, this consumption is mainly for cooling purposes. It means that the building envelope area and the total cooled floor area tend to increase as these variables increase. This will be as a result of the positive effect of R.H at ($\propto$ = 0.000), the building envelope at ($\propto$ = 0.009) and cooled floor area at ($\propto$ = 0.034) which are all positively significant to energy consumption. Furthermore, it signifies that comfortable indoor environment in the study area may not be achieved without air-conditioner, confirming Sangowawa and Mike Adebamowo (2010). However, it makes sense that viable ventilation mode in the study area remains mixed-mode for residential buildings.

Furthermore, the negative effects of energy consumption, as shown by indoor R.H at ($\propto$ = 0.000), indoor temperature at ($\propto$= 0.001), total eternal glazed area of ($\propto$ = 0.000) and general window sizes of ($\propto$ = 0.026) increase energy consumption as these variables increases in value. Design should therefore maintain good ventilation system through adoption of tropical bio-climate principles and be conscious of adequate opening to floor area ratios at most time.

5.2 SUMMARY OF FINDINGS

The research findings show that in most residential households in Lagos metropolis, energy consumption are in the range of 25KWh per week. This consumption only accounted for an average of six (6) hour daily electricity supply from the national grid, while other sources majorly fossil based generator is responsible for eighteen (18) hour daily supply of household consumption. This consumption rate accounted for most poorly orientated buildings of North South directions that do not encourage energy conservation. High percentage of the residential buildings was block of flats with gable roofs and eaves of less than 1metre projections. They were mixture of natural and mixed mode ventilated buildings, having less than 300m^2 cold floor areas. This population of residential buildings are mostly built with hollow sandcrete block, with asbestors ceiling, having an external circumference in the range of (50 – 100) meter, an external envelope area of (250 – 500) m^2 with a total floor area range of (250 – 500) m^2 not more than 25m length in the range of (1000 – 3000) m^3 building volume. Most of the households were fixed with a single glazed widows, of areas between (1 – 2.5)m^2 and a total external opening door and window area of (10 – 20)m^2, with an occupancy rate of five person family.

The identified energy consumption indicators in the study area includes seventeen building design factors (Table 4.9) that are found either significant or having a relationship with energy consumption among the twenty-two (22) identified residential building characteristics.

Importantly among them were the total cool floor area, building envelope area and general size of external glazing, as shown in the model building parameters. However, outdoor relative humidity and the indoor mean radian temperature are the environmental energy factors that show significant relationship to energy consumption. This is also indicated by the developed model. Further, this shows that there is a relationship between the outdoor and indoor relative humidity as a determining factor for energy consumption. The impact of the environmental factor is therefore shown by the relationship existing between the outdoor and indoor relative humidity and indoor radian temperature on energy consumption.

The occupant's behavioural action on energy consumption is shown by the significant relationship that exists between the use of window opening time which are mostly during the afternoon and evening periods when there are temperature swing. This is also explained by the significant relationship of the actions taken by the occupant during wet and dry condition that signified usage of fans and air conditioner periods.

The model developed for the prediction of energy consumption design parameters is found to be seven in numbers. These include both identified building characteristics and environmental factors. It is noted that occupant's behavioural actions are not inclusive. This is explained by the dependent relationship existing between the occupants' actions and other two factors, of environment and building design as shown in the present study's conceptual framework, (Fig. 2.23).

CHAPTER SIX:

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

This Study has investigated the energy consumption of selected residential buildings in Lagos with a view to attaining energy efficient housing environment. This was achieved through the use of existing literatures and field energy audit survey in 576 urban communities in Lagos metropolis.

The study has shown the lack of adequate knowledge of the relationship existing between building characteristics and planning layout. It has done this by focusing on how the control of extraneous environmental condition towards indoor thermal comfort attainment for the determination of occupants behavioural actions were responsible for the amount of energy consumption of most households and residences in Lagos. The identification of significant building design characteristic in the control of indoor environment in households and occupants' use of this control, as impact of energy consumption presented and discussed, has been found as a means to control energy consumption rate in Lagos.

The building design characteristics due to location, orientation, opening sizes, control uses, envelopes, floor ratios, roof types, roof overhangs and building choice of ventilation mode as it influence occupants' behaviour are necessities at the design inception through the adoption of integrated design of residences in Lagos metropolis.

The building planning should be made to involve a 3-dimensional planning. This will help to determine the relationship between one building orientation and others for the elimination of urban heat islands from poor layout planning and control of building envelopes, with respect to opening adequate sizes and orientations. This will control exposure of greater surface area of the buildings to unwanted solar radiation.

Building opening control, with respect to building orientations, will control indiscriminate punching of windows in undesirable sides of building envelopes for the control of indoor environmental condition of temperature and humidity that are significant to energy consumption. This has become necessary as shading devices of windows have given way to aesthetic, embellishment and under-sized windows of 1.80metre across Lagos, which do not relate to building floor area ratios.

Roof and Ceiling: The favourable high significance of roof designs with good eave overhangs should be further enhanced in the absence of adequate window shading devices. This is significant in contributing to the control of energy consumption, while eliminating overheat resulting from the inadequacies of flat roof and ceiling conditions which were found to be significant to energy consumption. This will also encourage the use of window opening operation and, consequently, adequate use of less energy consumption devices for the improvement of indoor air movement during outdoor milled conditions.

Building Mode: The adequacy of mixed mode ventilation choices of the residential buildings should be made compulsory through acts off legislation, as it is favourable to the control of energy consumption and found to be highly significant. This should be in vogue, as it adequately applies to the tropical bioclimatic design principles, applicable to the control of comfortable indoor condition and consequently energy consumption.

Occupants Behaviour: The responses of occupants with respect to maintaining differences in outdoor and indoor environmental variables of temperature and relative humidity through the available buildings characteristics control, is vital to energy consumption study. This is reflected in the relationship between living room opening time and use of other means of less energy intensive use of fans towards indoor comfort of occupants during hot humid and cold conditions. This is mostly controlled by the natural and mixed-mode main ventilation in the households, which should be encouraged for energy consumption control.

Finally, more clean energy consumption from alternative sources, mainly fossil fuel generator base, should be adequately controlled. This is in recognition of carbon emission which has been identified to be responsible for greenhouse gases and global warming. To achieve this, abundant use of solar generation is needed in the study area.

To summarise, optimisation of the residential building design through adequate building window to floor area ratios, opening sizes and maximizing planning orientations of east-west direction of buildings through the adoption of an integrated design to control energy consumption is necessary.

6.2 RECOMMENDATIONS

This study recommends that more emphasis on the knowledge of architectural sustainability should be encouraged in the training of architects and planners along with other professionals in the built environment. This adequate education of built environment professional on energy use and management is not only crucial to Architects and planners in the attainment of energy efficient housing built environment. It is also important to client in areas where adequate energy supply, energy data and building code standards are not readily available. The study therefore recommended that this gap be bridged urgently for an effective energy efficient housing built environment. It is also necessary for an interdisciplinary team to establish an energy bench mark for different climatic zones in Nigeria. This will enable the identification of energy performance index so as to pave way for energy consumption control. An important way to ensure occupant’s comfort, good health and safeguard the residential built environment is through formulation of legislation, building energy codes and standards. This could either be enforceable or in form of building energy consumption regulation or standards at regional and local government areas. It is also advisable to ensure that a well-funded periodic energy audit for energy performance of buildings is carried out periodically to ensure a sustainable energy future for Nigeria. While existing residential buildings could be made to undergo retro-fitting actions, new designs should be created to conform with energy efficient parameters that should be evolved by built environment professionals in the country. Additionally, building energy use experts should be trained across built professionals in the construction and the built environment to enhance sustainable energy future for Nigeria.

Finally, more research is also necessary to cover all the climatic zones in the country and cover other types of building such as high rise residential buildings, offices, schools and manufacturing factories etc.

6.3 CONTRIBUTIONS TO KNOWLEDGE

1. This study has contributed to knowledge, through the development of an energy consumption model useful for pre-design and post occupancy stages of residential buildings, this for the assessment, determination and control of residential building energy consumption in Lagos metropolis.
2. The study also identified outdoor relative humidity, indoor temperature and indoor relative humidity as environmental factors that are most significant variables to energy consumption in the households for the attainment of occupants required comfort. While at the same time identified thermal problem of residential building design in the study area as the major indicator to intensive energy consumption. This is as a result of non-application of tropical bioclimatic design principles, and practise of integrated design.
3. Lastly, the study has created the first monitored residential energy consumption data base to aid energy efficient residential building design, in Lagos in particular and Nigeria in general that enables the measurement of environmental and human behavioural variables in line with best global practise. While also responding to the challenges posed by the reality of climatic change in order to ensure a sustainable and stable energy future.

AREAS FOR FURTHER RESEARCH

1. Studies and experiments in characterising energy use in residential buildings be carried out to a reasonable level of climatic energy projections.
2. Studies on simulation modelling of building envelopes and climatic conditions.
3. Studies in the use of field results to develop energy efficiency index at different climatic zone of Nigeria by team of researchers and practitioners in the built environment.
4. Studies on the development of energy performance index for different building types in different climatic zone in Nigeria.
5. Studies to measure the carbon emission from fossil fuel base alternative energy sources in different types of buildings in Nigeria towards the development of renewable energy options.

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APPENDIX I

SET UP OF INSTRUMENT

APPENDIX II

ENERGY AUDIT

QUESTIONNAIRE

Department of Architecture, Faculty of Environmental Science, UNILAG

PhD Architecture on Energy Consumption in residential buildings in metropolitan Lagos, Nigeria.

This questionnaire is strictly for the collection of data for an on-going research that will culminate into PhD Architecture. All responses will be treated with the required ethics.
Thank you for your anticipated cooperation.

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ENERGY CONSUMPTION QUESTIONNAIRE

SECTION A: - **GENERAL INFORMATION**

Date		Time	
Room		Floor	
Address			

SECTION B: - **PERSONAL INFORMATION**

B1	Gender	(1) Male	(2) Female			
B2	Age	(1) <20	(2) 21-50	(3) >50		
B3	Height	(1) <1.5m	(2) 1.6-1.8m	(3) >2.0m		
B4	Weight	(1) <50kg	(2) 50-70kg	(3) >70kg		
B5	Activities Within Last Hour	(1) Working	(2) Sleeping	(3) Reading	(4) Relaxing	(5) Others
B6	Clothing	(1) Light	(2) Full Dress	(3) Sport Ware	(4) Casual	(5) Others

SECTION C: - **GENERAL BUILDING INFORMATION**

C1. Number of buildings on the property that are to be audited? ☐☐☐☐

C2. What is the Building year? ☐☐☐☐☐

C3. Have there been any major retrofit / conversion/ extension?
1.Yes ☐ 2. No ☐

C4. Year of major retrofit / conversion / extension?
Has not been performed. ☐☐☐☐☐

C5. Building location:
1. ☐ Local Government
2. ☐ Neighborhood area
3. ☐ Urban area
4. ☐ Suburb area
5. ☐ Rural area

C6. What type of building is been audited?
Single-family units
1. ☐ Detached house
2. ☐ Terrace house
3. ☐ Semi-detached house
4. ☐ Block of 6 flats
5. ☐ Bungalow
6. ☐ Rooming house

C7. Building description

7.1	Orientation	(1)North South	(2)East West	(3)SE/NW	(4)NE/SW	(5)Others		
7.2	Type of Building	(1)Residential	(2)Commercial	(3)Institutional	(4)Religious			
7.3	Size of Room	(1)<10 m^2	(2)11-20 m^2	(3)>30 m^2				
7.4	No of Occupants	(1)1-5	(2)2-10	(3)Others				
7.5	Form	(1)Triangular	(2)Rectangular	(3)Square	(4)Circular	(5)Poligon		
7.6	Wall Materials	(1)Solid Brick wall	(2)Hollow Sand Crete Block wall	(3)Concrete Wall	(4)Wooden wall			
7.7	Roof Materials	(1)Corrugated Asbestors	(2)Corrugated Aluminum	(3)Iron Sheet	(4)Reinforced Concrete Slab			
7.8	Ceiling Materials	(1)Asbestors	(2)Wooden	(3)P.O.P	(4)U.P.V.C	(5)Others		
7.9	Color of Ceiling	(1)White	(2)Blue	(3)Red	(4)Yellow	(5)Green	(6)Cream	(7)Others
7.10	Color of Wall	(1)White	(2)Blue	(3)Red	(4)Yellow	(5)Green	(6)Cream	(7)Others

WINDOW AND DOORS

C8. What types of windows? Tick the right box.
Single glazed [1] Doubled gazed [2]

C9. What is the total area of glazed part of external doors and windows? [ ] m^2

C10. What is the general size of glazed windows specify ranged [ ] m^2

C11. How many numbers of windows exist in the locations specify numbers and areas?

	No	M^2
(1) NE	[ ]	[ ]
(2) SW	[ ]	[ ]
(3) SE	[ ]	[ ]
(4) NW	[ ]	[ ]

ROOF

C12. What type of roof is in the building?
Flat [1] Gable [2] Hip [3] Others [4]

C13. What is the size of roof overhang / eave?
[1] 0 – 900cm [2] 1m – 1.5m [3] 1.5m and above [4] Not in existence [5]

C14. Which is the main ventilation type? (*Informative)*

1. [ ] Natural ventilation system
2. [ ] Controlled natural ventilation system
3. [ ] Mechanical
4. [ ] Balanced ventilation system
5. [ ] Mixed mode

C15. Give for the building (*plan drawing or ocular survey)*

15.1 Circumference (external dimension) [ ][ ][ ][ ] m^2
15.2 Longest length (external dimension) [ ][ ][ ][ ] m^2
15.3 Envelope area (external dimension) [ ][ ][ ][ ] m^2
15.4 Total floor area (internal dimension) [ ][ ][ ][ ] m^2
15.5 Residential cooled floor area (internal dimension [ ][ ][ ][ ] m^2
15.6 Total volume (external dimension) [ ][ ][ ][ ] m^3

SECTION D: - **ENVIRONMENTAL DESCRIPTION**

	Outdoor Condition		Weather Condition			
S/N	Items		Raining (1)	Cloudy (2)	Partly cloudy (3)	Bright (shiny) (4)
1.	Dry Bulb temperature (DBT)	^{o}C				
2.	Wet bulb temperature (WBT)	^{o}C				
3.	Globe thermometer reading (GTR)	^{o}C				
4.	Mean radiant temperature (MRT)	^{o}C				
5.	Relative Humidity (RH)	^{o}C				
6.	Velocity (V)	m/s				

	Indoor Condition		Weather Condition			
S/N	Items		Raining (1)	Cloudy (2)	Partly cloudy (3)	Bright (shiny) (4)
1.	Dry Bulb temperature (DBT)	^{o}C				
2.	Wet bulb temperature (WBT)	^{o}C				
3.	Globe thermometer reading (GTR)	^{o}C				
4.	Mean radiant temperature (MRT)	^{o}C				
5.	Relative Humidity (RH)	^{o}C				
6.	Velocity (V)	m/s				

SECTION E:- **THERMAL BEHAVIOUR AND CONTROL**

		07 – 12 MORNING (1)	13 – 18 NOON (2)	19 – 24 EVENING (3)	01 – 06 NIGHT (4)
1.	**When do you open the windows in your living Room?**				
2.	**When do you usually switch on your fan? (fan include standing, desk or ceiling fan)**				
3.	**Do you have an air-conditioner unit in your flat? Yes / no If yes, when do you usually switch on the AC?**				
4	**If you experiencing a hot and humid condition how do you make yourself more comfortable?**				
a.	Take bath more often	1			
b.	Change my cloth to light clothing	2			
c.	Get more cold drink	3			
d.	Open windows and doors wide	4			
e.	Switch on fan	5			
f.	Switch on Air-conditioner	6			
g.	Go outside for fresh air or to the cooler places	7			
5	**If you experiencing cold, how do you make yourself more comfortable?**				
a.	Take a hot shower				
b.	Change my cloth to heavy clothing	1			
c.	Closing the windows	2			
d.	Switch off the fan	3			
e.	Turn up some lighting fixtures	4			
f.	Lighting a fire or heater	5			
g.	Curling up or cuddling up	6			
		7			

SECTION F: - **ELECTRICITY METER INFORMATION**

F1. Does the building have its own electricity meter, with no other buildings included?

1. Yes ☐ 2. No ☐

F2. Which electrical meters exist for the building?

Meter 1 ☐☐☐☐☐☐☐☐☐☐ Meter 2 ☐☐☐☐☐☐☐☐☐☐ Meter 3 ☐☐☐☐☐☐☐☐☐☐

F3. The meter reads the following (more than one alternative possible Yes = 1 No=2

	Meter 1	Meter 2	Meter 3
Household electricity	1. ☐	1. ☐	1. ☐
Electrical space heating	2. ☐	2. ☐	2. ☐
Electrical space cooling	3. ☐	3. ☐	3. ☐
Hot water boiler	4. ☐	4. ☐	4. ☐
External lighting	5. ☐	5. ☐	5. ☐

Other electricity use on the property

F4. Are there other electrical devices or building on the property which use the same electricity meter?
1. Yes ☐ 2. No ☐

F5. Are there any other electricity supply source in the building, tick approprate.
1. Gas ☐ 2. Solar ☐ 3. Generator ☐ 4. Others ☐

F6. Describe the object here and write, if possible, rated power and run time as a percentage for the seasons. Yes = 1 No=2

Meter/subscription	Rated power	Run time Winter	Run time summer	
(1) Exterior lighting	☐☐☐ Kw	☐☐☐ %	☐☐☐ %	☐☐☐☐☐☐
(2) Electric cooker	☐☐☐ kW	☐☐☐ %	☐☐☐ %	☐☐☐☐☐☐
(3) Water heater	☐☐☐ kW	☐☐☐ %	☐☐☐ %	☐☐☐☐☐☐
(4) Washing machine	☐☐☐ kW	☐☐☐ %	☐☐☐ %	☐☐☐☐☐☐
(5) Pool heaters and pumps	☐☐☐ kW	☐☐☐ %	☐☐☐ %	☐☐☐☐☐☐
(6) Exterior sauna	☐☐☐ kW	☐☐☐ %	☐☐☐ %	☐☐☐☐☐☐
(7) Fans	☐☐☐ kW	☐☐☐ %	☐☐☐ %	☐☐☐☐☐☐
(8) Air conditioner	☐☐☐ kW	☐☐☐ %	☐☐☐ %	☐☐☐☐☐☐
(9) Refrigerator	☐☐☐ kW	☐☐☐ %	☐☐☐ %	☐☐☐☐☐☐

F7. What time is the property mostly occurred.
(1) Morning 07 – 12 (2) Noon 13 – 18 (3) Evening 19 – 24 (4) Night 01 – 06

F8. How many hours of the day is electricity supply available for use ☐ hrs/day ☐ Hrs/week
(1) 1-5Hrs (2) 6-10Hrs (3) 11-15Hrs (4) 16-24Hrs

F9. **SUPPLIERS**

Energy supplier name, address	Subscript / account	Meter number
1 PHCN		
2 IKEJA ELECTRIC		
3 EKO ELECTRIC		
4 OTHERS		

F10. **METER READING/ ENVIRONMENTAL DESCRIPTION**

NO	DATE	DAY	METER READING	ENERGY CONSUMPTION
1				
2				
3				
4				
5				
6				
7				

APPENDIX III

FIELD STUDIES DATA