THE IMPACT OF GREEN BUILDINGS IN CLIMATE CHANGE MITIGATION: AN INVESTIGATIVE STUDY ON SELECTED OFFICE BUILDINGS IN WESTLANDS, NAIROBI COUNTY

BY

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A RESEARCH PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF MASTERS OF ARTS (M.A) DEGREE IN ENVIRONMENTAL PLANNING AND MANAGEMENT (EPM) AT THE DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES UNIVERSITY OF NAIROBI.

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Declaration

This Research Project is my original work and it has never been presented for a degree in any other University.

SIGN: .... DATE: 07/11/2012

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(C50/76292/2009)

This Research Project has been submitted for examination with our approval as the University Supervisors

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Dedication

To my Beloved Parents

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Acronyms and Abbreviations

ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers

BREAM - Building Research Establishment's Environmental Assessment Method

CBD - Central Business District

CCN - City Council of Nairobi

CFCs - Chlorofluorocarbons

CH_4- Methane

CO_2 - Carbon Dioxide

E1A -Energy Information Administration

GCI – Galvanized Corrugated Iron Sheets

GHG - Green House Gases

HVAC - Heating, Ventilating, and Air-Conditioning systems

H_2O - Water vapour,

HFCs - Hydro fluorocarbons

IPCC - Inter-Governmental Panel on Climate Change

NCBDA - Nairobi Central Business District Association

KMD -Kenya Metrological Department

KNBS -Kenya National Bureau of Statistics

LEED - Leadership in Energy and Environmental Design

N_2O - Nitrous oxide,

O_3 - Ozone

SPSS - Statistical Package for Social Scientists

UNEP - United Nations Environmental Program

UNFPA - United Nations Population Fund

NW&SC – Nairobi Water and Sewerage Company

VOC – Volatile Organic Compounds

PVC – Poly Vinyl Chloride

Abstract

Climate Change is one of the major global environmental challenges facing the world today. Devastating impacts on the environment such as, hurricanes, typhoons, floods, droughts and global warming have been wide-reaching due to rapid increase of anthropogenic greenhouse gases (GHG) into the atmosphere. This has been aggravated by rapid urbanization and growth in the building and construction sector. The building sector is among biggest consumers of energy globally and consequently one of the largest emitter of GHG and consequently a leading contributor to anthropogenic climate change.

The main objective of this research was to establish if there are green buildings within the area of study in the Westlands area of Nairobi, and subsequently determine their impact on climate change mitigation if any. This study looked at "green buildings" as a measure to mitigate and adapt to the vulnerability and impacts of climate change particularly GHG that are produced by buildings. "Green Buildings" can be defined as those buildings that are deliberately designed such that they emphasize on, sustainable site development, energy and water efficiency, healthy indoor environmental quality and sustainable usage materials and resources with minimal negative impacts on human health and the environment. The study covered 33 buildings within zone 3 of the Westlands area of the Nairobi Central Business District (CBD). This translates to 64% of the buildings within the area of study.

The research established that most buildings within the area of study do not qualify as green buildings. However, other buildings within the greater Nairobi such as the New United Nations Environment Programmee (UNEP) and UN-HABITAT Office Building in Gigiri, Nairobi Kenya offers an ideal case study of how buildings within the tropical climate can be designed and built to effectively reduce GHG that are produced by buildings. This research recommends the setting-up of a Kenya Green Building Council which will be mandated with spearheading the green building agenda in Kenya.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Just like hunger, poverty and food insecurity, climate change is one of the major global environmental challenges facing the world today. In the recent past, the devastating impacts of climate change and vulnerability are on the increase. This has been aggravated by the rapid increase of anthropogenic GHGs into the atmosphere that are greatly responsible for climate modification hence climate change (UNEP, 2007).

Increased infrastructural development and rapid urbanization in the developing countries and the emerging economies has proportionately increased the demand for fossil fuels in transportation, manufacturing, building and construction sectors resulting into more GHG emissions. The building sector is amongst the biggest consumers of global natural resources, potable water and energy. Furthermore, a substantial amount of global solid wastes come from buildings filling up dumping sites in many cities which are significant sources of methane and nitrous oxide gases (IPCC, 2001).

Based on the aforementioned challenges, climate change should be mitigated through a multi-pronged. A paradigm shift in the way we design and construct buildings is one such approach, through "green building design". "Green Buildings" are those buildings that are deliberately designed to meet specific objectives such as, sustainable site development, energy and water efficiency, healthy indoor environment quality, sustainable usage materials and resources with minimal negative impacts on human health and the environment (Yeang, 1995).

Embracing green building design during the construction of new buildings, and retro-fitting of existing ones provides one of the sustainable ways combating climate change, reduce running costs on buildings increase occupant health and productivity. In addition, renewable energy and green transportation are a central part of the transition to a "Green Economy" responsible for creating green jobs which are decent and sustainable in the long-term through technological innovation geared towards creating a low-carbon and sustainable 21st century (UNEP, 2008).

1.2 Statement of the Problem

According to the Fourth Assessment Report of the Inter-Governmental Panel on Climate Change (IPCC, 2007), the building sector is among the biggest consumers of energy globally. Most of this energy is produced from burning fossil fuels during; the construction process, operation and maintenance, demolitions, renovations and retrofitting. This makes this sector amongst the largest emitters of greenhouse gases (GHG) and one of the leading contributors to anthropogenic climate change (IPCC, 2007).

According to Lenssen (1995) observations on the sources of urban GHG emissions, manufacturing of building materials contributes up to 4 billion tonnes of carbon dioxide (CO_2) emissions annually. All the production stages from mining of raw materials to production of finished products imply a number of negative impacts to the environment. To compound this environmental concern, the building sector consumes materials with high embodied energy content specifically; aluminum, cement and steel, whose production results in greater CO_2 emissions. This compounds the problem even further and hence the need to embrace means and ways of reducing the embodied energy in order to reduce the ecological footprint of buildings.

With population explosion in urban centres and rapid urbanization, the consumerism culture is on the increase. More resources are invested in the cities and consequently producing more wastes too. Poor waste management polices by municipal authorities encourage dumping which is one of the sources of methane and nitrous oxide gases. Expansion of oxidation ponds for urban sewage treatment plants to cater for increased urban population and incineration of solid wastes are other potential sources of GHG emissions (Petersen 2002).

The building and construction sector is also responsible for significant emission of non-greenhouse gases such as halons, chlorofluorocarbons (CFCs) hydrofluorocarbons (HFCs) which contribute to the depletion of the stratospheric ozone. CFCs are mainly used in heating, ventilating, and air conditioning (HVAC) systems in building. Air-conditioning systems are among the big consumers of energy in buildings and substantial consumers of CFCs to achieve thermal comfort in buildings. Furthermore, HFCs constitute the main raw material for making foam which is used as an insulation material in roofs and cavity walls especially in temperate regions, while halons constitute the main solvent in fire extinguishers used in buildings (Levine et al, 2007).

According to the Inter-Governmental Panel on Climate Change (IPCC) Fourth Assessment Report (2007), improved energy and resource efficiency in the buildings sector offers more potential for cost-effective GHG emissions reductions (Figure 1.1) than any other major abatement category in climate change mitigation. In addition the U.S Energy Information Administration (EIA) shows that advanced innovations in energy-efficient building technologies, provide a good opportunity for reducing carbon emissions at a low or negative net cost reducing projected energy use in buildings by 41% by 2050, thereby avoiding 11.5 gigatonnes of CO_2, or roughly 40% of current global fossil CO_2 emissions (EIA, 2009).

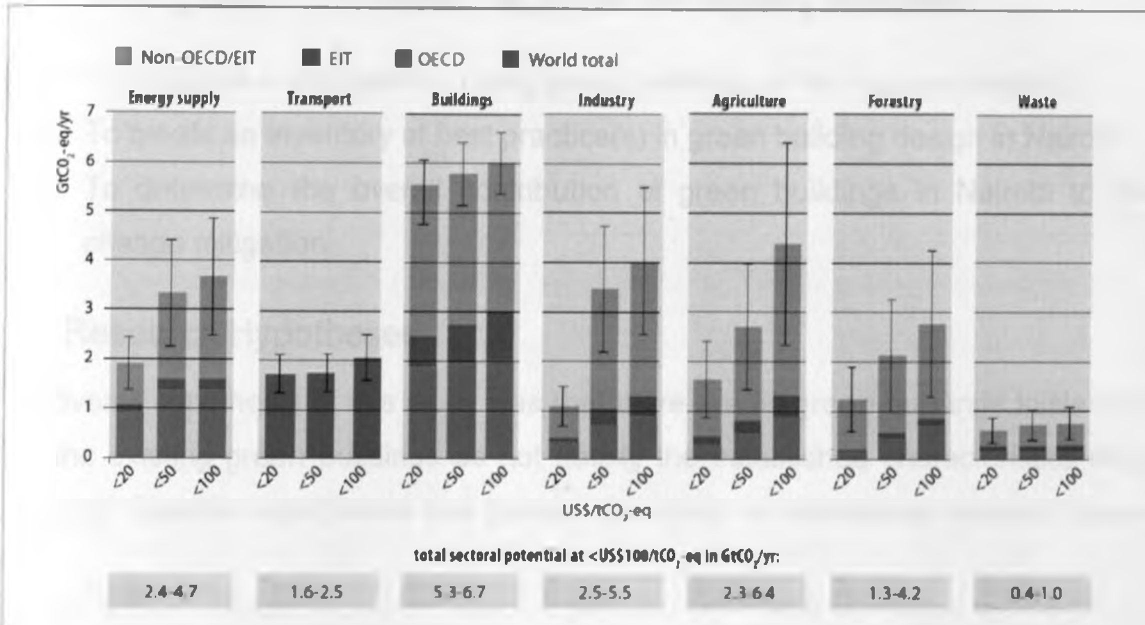


Figure 1.1: IPCC projections of CO_2 mitigation potential by various economic sectors by 2030

Source: IPCC Synthesis Report (2007), Page 59

To confront this burgeoning environmental challenge, a paradigm shift in architecture and building design is inevitable. Buildings that show these attributes of sustainability are called "green buildings". According to Yeang (1995), a green building is defined as; 'A building that unites a high comfort level with optimum user quality through; energy and water efficiency; minimal environmental degradation and at the same time meeting the most stringent demands for aesthetics and function. The building sector has immense capacity to offer significant solutions to climate change mitigation and adaptation amongst other abatement categories hence the genesis of this research.

The specific research questions addressed by this study were:

1. What considerations are required in the design of green buildings?
2. Do green buildings exist in Nairobi?
3. What is the overall contribution of green buildings in mitigating climate change in Nairobi?

1.3 Objectives of the Study

The building and construction sector is offering this research study an opportunity to investigate and establish ways and means of providing alternative solutions through green building design. This research study has the following objectives:

1. To establish a standard for rating green buildings in the Kenyan context.
2. To create an inventory of best practice(s) in green building design in Nairobi
3. To determine the overall contribution of green buildings in Nairobi to climate change mitigation.

1.4 Research Hypotheses

The overall hypothesis of this study was that there are no green buildings in Nairobi and that the existing green buildings do not satisfy the established characteristics of green buildings. Specific hypotheses that guided this study in addressing research questions are:

1. There is no common standard for the design of green buildings in Nairobi.
2. Buildings in Nairobi do not qualify as green buildings.
3. The existing green buildings in Nairobi make no contribution to climate change mitigation.

The Null Hypothesis (H_0)

Buildings in Nairobi do not qualify as green buildings.

The Alternative Hypothesis (H_1)

Buildings in Nairobi qualify as green buildings.

1.5. Area of study

1.5.1. Location and Size

Nairobi is located at the south-eastern end of Kenya's agricultural heartland, at approximately 1° 9'S, 1° 28'S and 36° 4'E, 37° 10'E. It occupies an area of about 696km^2.The altitude varies between 1,600 and 1,850 metres above sea .The western part of Nairobi is on high ground between 1700–1800 metres above sea level with rugged-stone topography, the eastern side is generally low and flat at 1600 metres above sea level. Key physical features include the Nairobi, Ngong and Mathare rivers and the indigenous Karura forest in the north and the forested Ngong hills towards the west (Saggerson, 1991).

The former Nairobi Province has been renamed Nairobi County which also forms the boundaries of the city of Nairobi, the capital city of Kenya. With the implementation of Vision 2030, Nairobi County, together with the neighbouring counties of Kiambu, Machakos and Kajiado, will be integrated to form the greater Nairobi Metropolis (Figure 1.2) whose mission will be to propel its residents to a middle-income status with improved infrastructure, social and economic wellbeing by the year 2030 (KNBS, 2000).

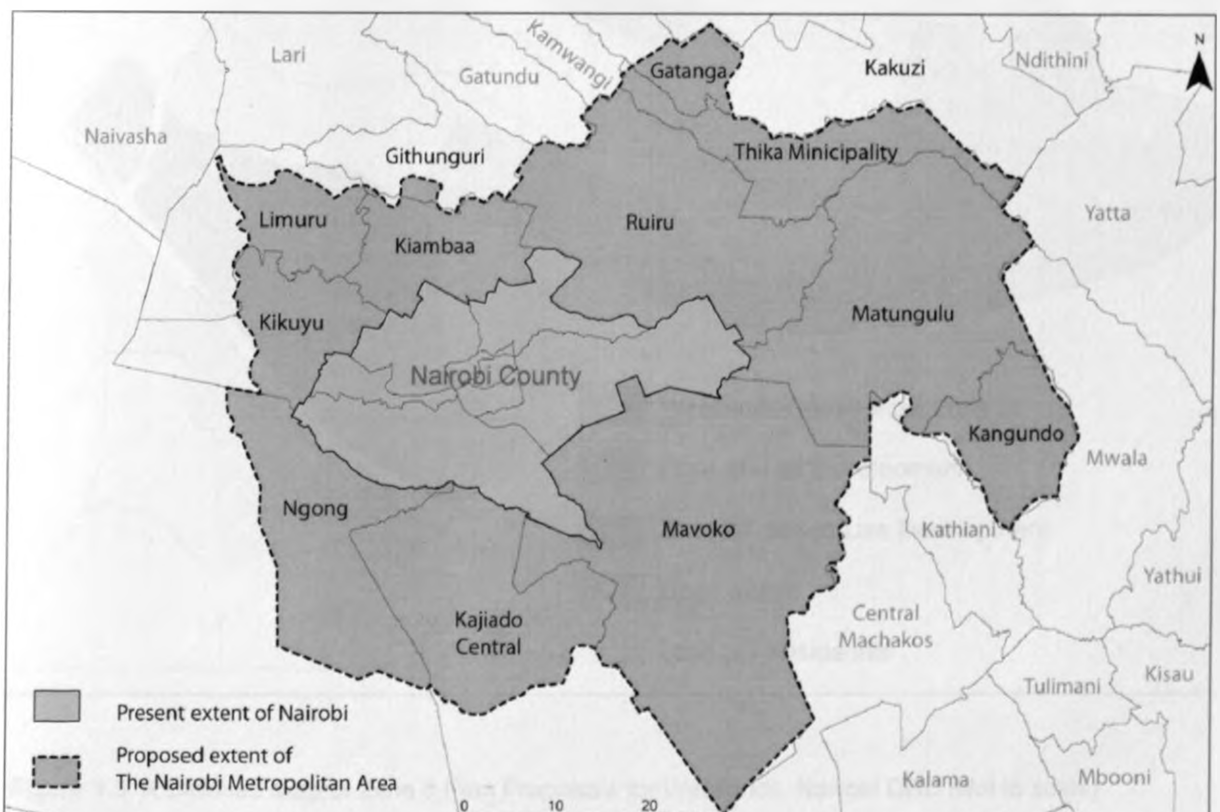


Figure 1.2: A Map of The greater Nairobi Metropolitan Area

Source: Planning Department, City Council of Nairobi (2010)

In 1995, the City Council of Nairobi, in conjunction with the Ministry of Lands, approved a re-planning and rezoning land-use policy which designated and expanded existing commercial centres by granting change-of-use permission in the Upper Hill, Hurlingham, Yaya, Valley Arcade and Lavington areas (Figure 1.3). The present Nairobi Central Business District (CBD) is a multilayered city centre with Satellite Centres with vibrant commercial and social functions. These centres include: Westlands, Parklands, Lavington, Hurlingham, Upper Hill, Langata and Buruburu in the greater Eastlands area (Mitullah 2002). According to a report on crime and business environment within the CBD by the Nairobi Central Business District Association-NCBDA (2008), traffic congestion, pollution, crime and shortage of office space in the city centre has seen the rapid growth of the satellite areas of Upper Hill and Westlands into preferred locations for office buildings in the city.

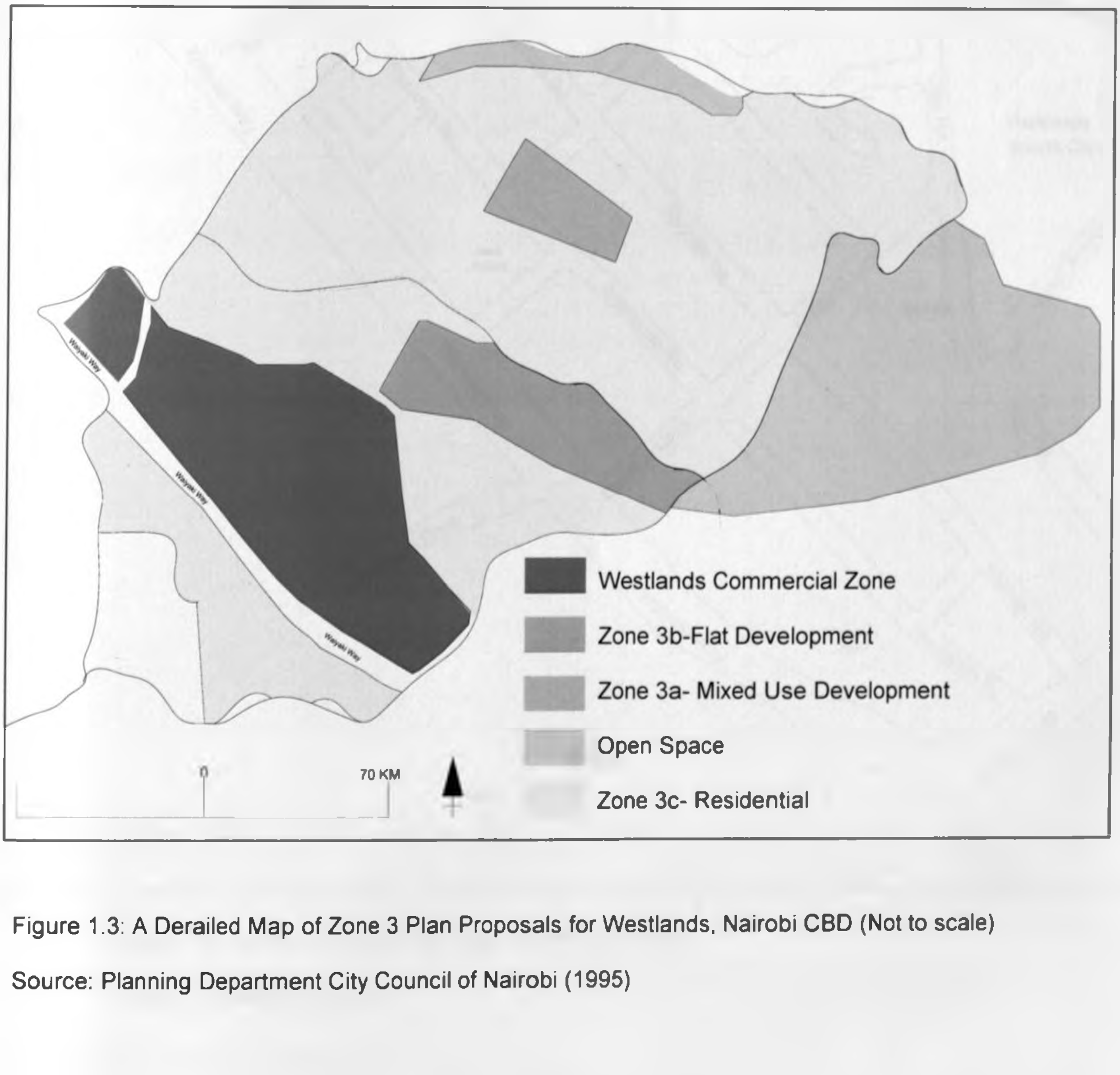


Figure 1.3: A Derailed Map of Zone 3 Plan Proposals for Westlands, Nairobi CBD (Not to scale)

Source: Planning Department City Council of Nairobi (1995)

The study was done in zone 3 of the greater Nairobi Central Business District which encompasses the Westlands CBD and the Museum Hill areas. The study area is delineated by Chiromo Road, Museum Hill Road, Ojijo Road, Parklands Road, Ring Road Parklands, joining Waiyaki way at the Pio Gama Pinto Street (Figure 1.4).

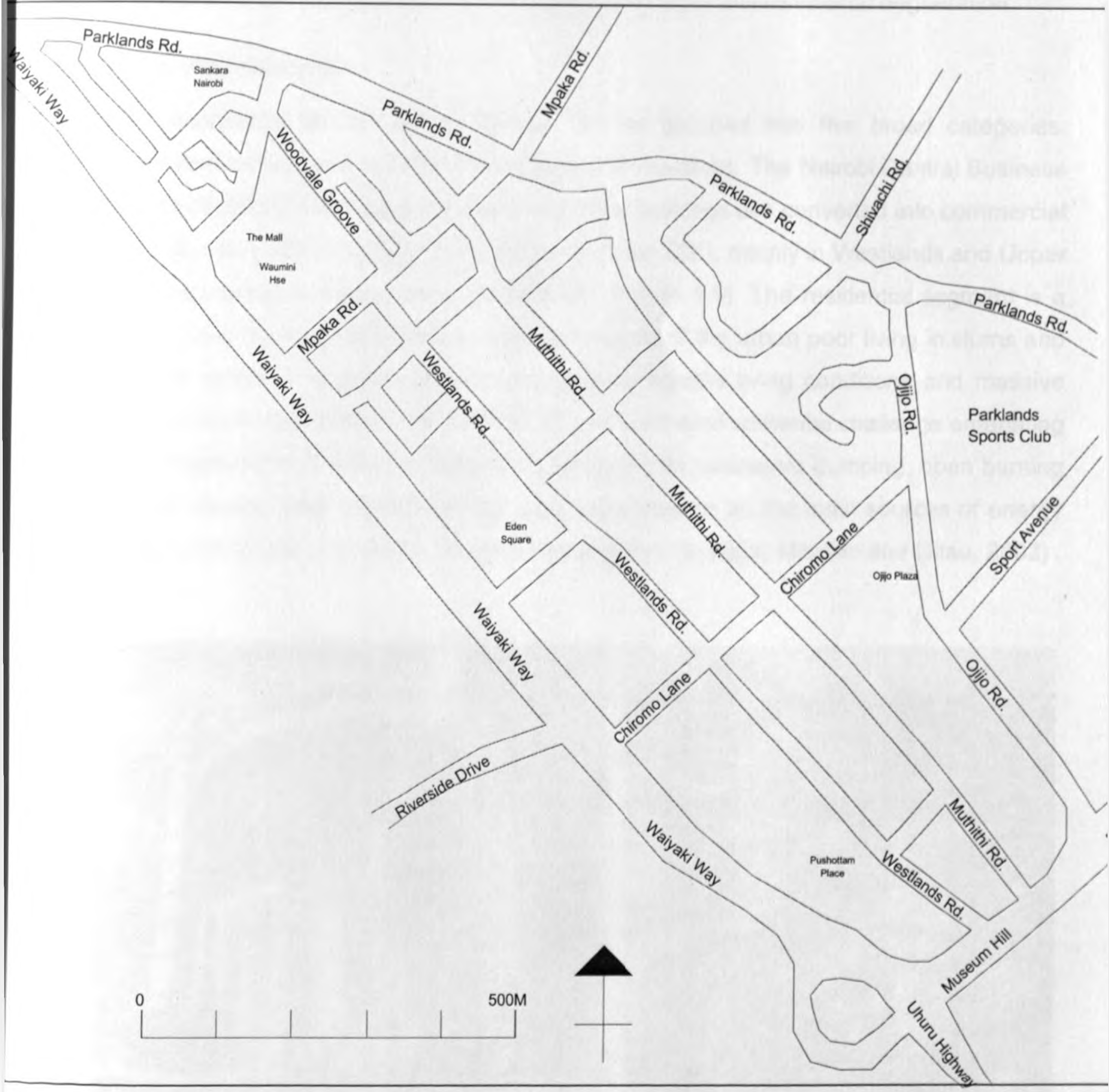


Figure 1.4: A Map of Nairobi showing the Area of Study

Source: Research, (2012)

1.5.2. Population

The 2009 Kenya Population and Housing Census Report by the Kenya National Bureau of Statistics, indicates that Nairobi is domiciled by 3.1 million people. Rapid urbanization from rural urban migration has overstretched the existing infrastructural services leading to many socio economic challenges such as unemployment, traffic congestion, sprawling of slums and informal settlements and more significantly environmental degradation.

1.5.3. Architecture

The architecture of the city of Nairobi can be grouped into five broad categories: residential, offices and commercial and industrial buildings. The Nairobi Central Business District (NCBDA) statistics show that most office buildings are converted into commercial use with many offices shifting to the outskirts of the CBD, mainly in Westlands and Upper Hill areas owing to their serene environment (Figure 1.5). The residential segment is a mosaic of all types of settlements, with the majority of the urban poor living in slums and informal settlements which are characterized by squalid living conditions and massive environmental degradation. Air pollution is one such environmental challenge emanating from urbanization of informal settlements (Figure 1.6), excessive dumping, open burning of solid wastes, over reliance on charcoal and kerosene as the main sources of energy greatly contributes to emission of greenhouse gases (Syagga, Mitullah and Gitau, 2002)

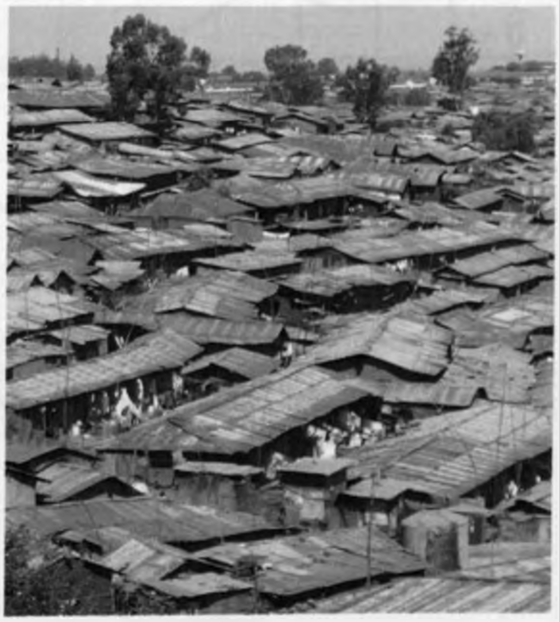


Figure 1.5: A Photo of an upcoming 9 West Office Block in Westlands, Nairobi. Figure 1.6: A photo of the Sprawling Kibera Slums, in Nairobi

Source: Research (2012)

1.5.3. Climate

Nairobi has a tropical island climate (Figure 1.7). There are two distinct rain seasons in a year, i.e. long rains from May to March and short rains in October to December. The mean annual rainfall ranges between 850-1050mm. Radiation is strong and often with moderate cool air temperatures with the mean daily sunshine hours varying between 3.4 and 9.5 hours (Mitullah, 2003).

The average temperature in Nairobi is 17.7 °C (64 °F). It is usually dry and wet between July and August, but hot and dry in January and February. The mean monthly relative humidity varies from 36% to 55 %. The annual mean temperature is 24.5°C and the diurnal temperature range is 13.1°C. Humidity is not excessive, and there is an almost constant air movement from prevailing and secondary winds which are easterly and north easterly respectively with a mean max speed of 6.7m/s and a mean min. value of 3.1 m/s. (KMD, 2011)

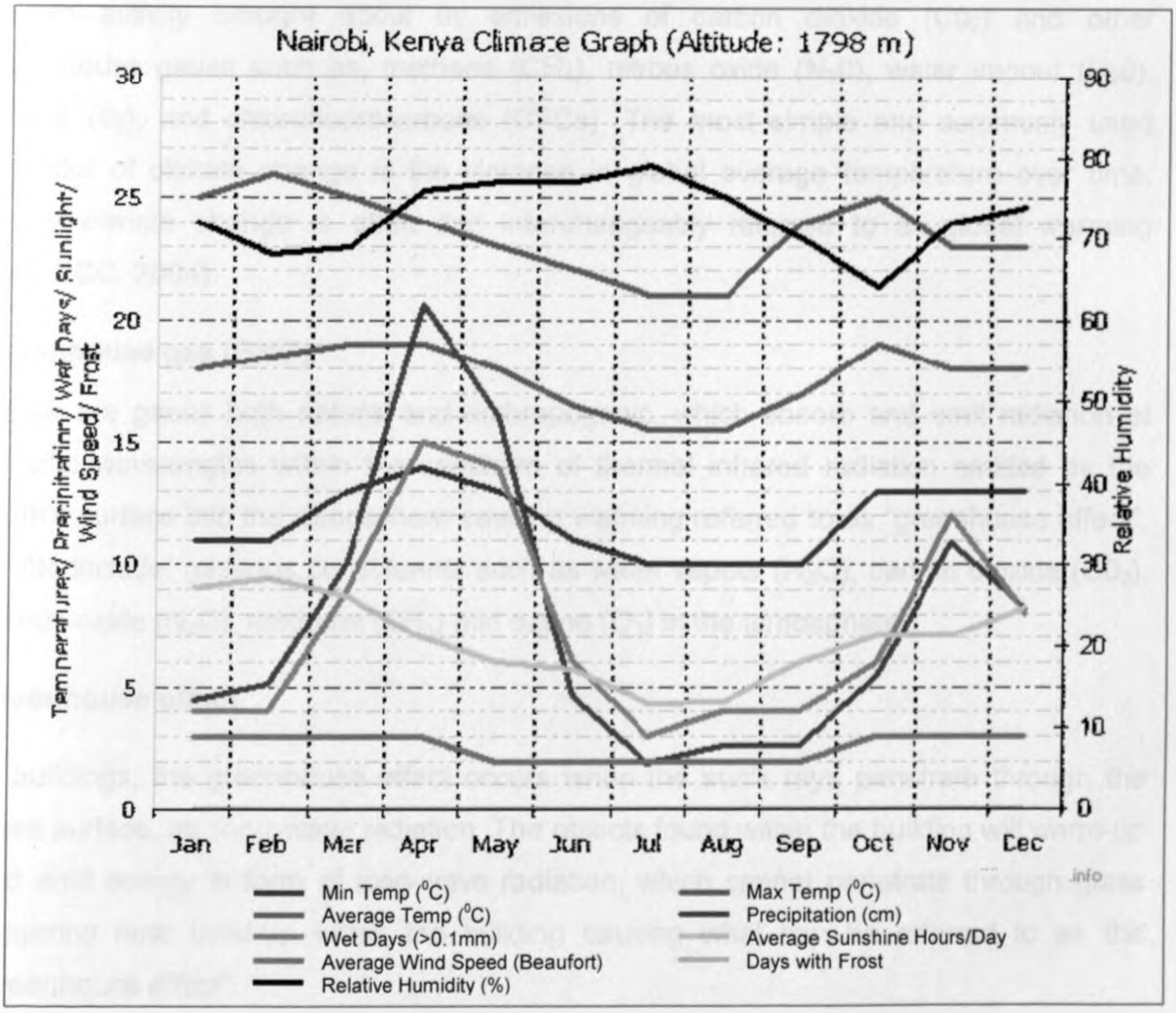


Figure 1.7: A graph showing the Climate of Nairobi, Kenya

Source: Kenya Metrological Department (2003)

1.6. Operational Definitions

Carbon Footprint

This is defined as the measure of the exclusive global amount of carbon dioxide ($C0_2$) and other greenhouse gases emitted by a human activity or accumulated over the full life cycle of a building. The energy use includes that used for the manufacture and harvest of products used in construction of a building, and the operation of a building such as heating, cooling and lighting.

Climate Change

The United Nations Framework Convention on Climate Change defines climate change as "a change of climate" which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural variability observed over time. Alternations are due to natural variability or as a result of human activity brought about by emissions of carbon dioxide ($C0_2$) and other greenhouse gases such as, methane (CH_4), nitrous oxide (N_20), water vapour (H_20), Ozone (0_3), and chlorofluorocarbons (CFCs) .The most simple and commonly used indicator of climate change is the increase in global average temperature over time, hence climate change is often and interchangeably referred to as global warming (UNFCCC, 2004).

Greenhouse gas (GHG)

These are gases both natural and anthropogenic, which absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the earth's surface into the atmosphere causing warming referred to as "greenhouse effect". GHGs include; gaseous constituents such as water vapour (H_2O), carbon dioxide ($C0_2$), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) in the atmosphere.

Greenhouse effect

In buildings, the greenhouse effect occurs when the sun's rays penetrate through the glass surface, as short-wave radiation. The objects found within the building will warm-up and emit energy in form of long-wave radiation, which cannot penetrate through glass triggering heat build-up within the building causing what can be referred to as the "greenhouse effect".

Green Building

A green building also known as a 'sustainable building' or a 'high performance building' can be defined as a structure that is designed, built, renovated, operated, or reused in an ecological and resource-efficient manner. Green buildings are designed to meet certain objectives such as; protecting occupant health; improving employee productivity; using energy, water, and other resources more efficiently; and reducing the overall impact to the environment.

Mitigation

A human intervention to reduce the sources or enhance the sink of greenhouse gases

In-situ Construction

Construction method where everything is done on site

Fenestrations

Openings in a building such as windows and doors

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. Introduction to Literature Review

This chapter takes an overview at the existing information on "green building" and the global trends on mitigation and adaptation to climate change through green building design. This research interrogates the study objectives with the aim of providing a practical definition of a green building in the Kenyan context, by determining the characteristics of a green building design to enable the researcher create an inventory of green buildings in Nairobi within the area of study. Finally this study research suggests a system of rating green buildings as a measure of climate change mitigating.

This chapter is structured into three sections; First, the section on buildings and climate change takes a global outlook at the possible impacts on buildings in particular and the built environment in general have on climate change in the context of building climatology .Secondly, a vivid look at the global green building rating systems gives a foresight into an organized way of rating buildings with an aim of establishing one suitable for the Kenyan context. Thirdly, it delves into the components of green building design which will eventually inform the research on data collection. Lastly, a case study on a green building was done to inform the research further.

2.2. The Review

2.2.1. Buildings and Climate Change

The principles of building green date back to many types and forms of traditional and vernacular architecture around the world, where buildings were built and designed with climate. These buildings were inherently 'green-oriented' to maximize on the benefits of natural environment such as natural lighting, ventilation and appropriate building materials. The contemporary green building movement arose out of the need and desire for more energy efficient and environmentally friendly building practices. The energy crisis of the 1970s spurred significant research and activity to improve energy efficiency and find renewable energy sources. This, combined with the environmental movement of the 1960s, led to the earliest experiments with contemporary green building. The green building movement began to come together more formally in the 1990s (Denyer, 1978).

With the advent of heating and air conditioning (HVAC) systems in the twentieth century, there was a dramatic shift in the way buildings were being designed. Many designers would prefer to go for easier alternatives by altering the internal environment of buildings rather than designing in response to external climatic conditions (McDonough and Gissen, 2002). With the advent of (HVAC) systems, the Building and Construction Sector is also responsible for significant non-CO_2 GHG emissions such as halocarbons, CFCs, and HCFCs which are covered under the Montreal Protocol, and hydro fluorocarbons (HFCs), due to their applications for cooling, refrigeration. Halocarbons on the other hand, are used in the manufacture of foam which is used an insulation material in buildings (UNEP, 2001).

With the rapid growth of the building sector, buildings became one of the major consumers of energy and sources of GHGs. With the energy crisis of the 1970s, there was a push to build energy efficient and green buildings. Most governments especially in developed countries provided incentives to encourage technological innovations. With time, the movement became more of a trend and it died off. Today the large energy footprint of buildings and their role in contributing to climate change are finally being realized, the building community is on a rebound to design and construct more energy-efficient buildings to help reverse the negative impacts buildings have on the environment, hence the many reasons to the resurgence of green design movement (Yeang,1995).

In reference to the Fourth Assessment Report of the IPCC (2007), buildings are responsible for more than 40% of global energy used, and as much as one third of global greenhouse gas emissions, both in developed and developing countries. It is estimated that building-related GHG emissions to be around 8.6 million metric tons CO_2 eqv by 2004. The rate at which GHG emissions have been on the rapid increase between 1971 and 2004, CO_2 emissions in buildings mainly through the use of electricity in buildings during the operation phase, is estimated to have grown at a rate of 2.5% per year for commercial buildings. The building sector has a considerable potential for positive change, to become more efficient in terms of resource use, less environmentally intensive and more profitable by adopting green building design strategies. Sustainable buildings can also be used as a mitigating opportunity for greenhouse gas emissions under the flexible mechanisms under the Kyoto Protocol (Levine et al, 2007).

2.2.2. Components of a Green Building

This section discusses the components of a green building by taking an in depth look at the elements that constitute a green building design.

2.2.2.1. Sustainable Site Development

The most important element of green building simply begins with site selection. The basic intent of this strategy of green building is to utilize the site such that there is minimum project's impact on the site and long-term environmental impact the building may pose Proper site selection help to minimize native vegetation disturbance, locate and site facilities to avoid cutting mature vegetation, minimize the visual impact by using natural vegetation and adjust the building plan to minimize the visual impact by the buildings (Kubba, 2010).

The overall impact on soil erosion and sedimentation control on natural hydrological system can be minimized by proper siting and designing of the building. Safeguarding hydrological systems from contamination during and after construction is of great importance too. Use permeable paving like grass and avoiding large impervious surface areas to allow ground seepage to naturally recharge groundwater. Correct orientation of the building along the east-west axis allows for the maximum winter solar gains and lower summer solar gains, hence minimizing the need for air conditioning. Vegetation, walls, fencing can be used to minimize ground-level wind loads control winds at ground level (O'Brian, Mary, and Nile, 2003).

Focusing on proper storm water design minimizes the amount of storm water run-off from the building site and maximizing the time lag for surface run-off. Often the techniques used are architectural (such as vegetative/green roofs), landscaping (pervious pavements, bio-swales), and civil (detention basins, filtration). However, for a more sustainable solution, focus should be directed to on- site storm water collection, storage, and reuse (McGraw, 2008).

According to Woods (2008) discussions on sustainable site development, heat island effect is a critical element for controlling the outdoor environment around any building. The colour and reflectance of the building roof and of the surrounding paving have a significant impact on cooling loads inside the building and on the local microclimate through the heat island effect. Shading of buildings using trees helps in reducing the temperature of the local microclimate, hence less need for air conditioning.

Material surface	Solar Reflectance	Emittance	SRI
Black acrylic paint	0.05	0.9	0
New asphalt	0.05	0.9	0
Aged asphalt	0.1	0.9	6
"White" asphalt shingle	0.21	0.91	21
Aged concrete	0.2 to 0.3	0.9	19 to 32
New concrete (ordinary)	0.35 to 0.45	0.9	38 to 52
New white Portland cement concrete	0.7 to 0.8	0.9	86 to 100
White acrylic paint	0.8	0.9	

Table 2.2: A table showing solar reflectance (albedo), Emittance, and Solar Reflective Index (SRI) of selected material surfaces
Source: USGBC, (2011).

2.2.2.2. Water Efficiency

The basic intent of this strategy is to provide water-efficient practices, both indoor and outdoor. According to McDonough and Gissen (2002), water efficient landscaping is aimed at reducing the amount of water used for irrigation purposes. Use of native plant species that are drought resistant and use of plant shading can make a significant difference in water demand for landscaping irrigation hence reducing water demand.

According to Yoders (2008), innovative wastewater technologies are becoming more popular alternatives in achieving sustainable and efficient water usage. Once the water usage is reduced to a minimum treating the wastewater on-site is highly recommended. There are two basic approaches to this: a grey water treatment system, which clarifies waste water that does not contain human fecal matter, and a black water treatment system that treats sewage regardless of its content. The reclaimed water can be used for non-drinking functions such as; toilet flushing or landscape irrigation.

Similarly, rainwater harvesting systems can supply a typical building with entire water needs, including their potable water. A proper system that combines rainwater catchment, storage, filtering and recycling to supply buildings with an efficient and renewable water supply offers an integrated alternative to the erratic municipal water supply (Fowler and Rauc, 2006).

Water-use reduction is another area where water efficiency can be realized within a building. This strategy primarily impacts plumbing in terms of reducing the total potable water used by the building and minimizing the impact of that water-use on the sanitary and storm water systems. There are opportunities for potable water reductions, both through use of water-efficient fixtures and fittings and through the use of reclaimed water in cases where it is available. The reduction of potable water usage can be achieved through more water-efficient plumbing fixtures. Some of the water-efficient plumbing fixtures include: low-flow lavatory and shower aerators, auto-controls, dual-flush water closets, ultra-low-flow urinals, and waterless urinals (Lee and Burnett, 2008).

2.2.2.3. Energy Efficiency

Energy efficiency and conservation is undoubtedly the most important part of building green since it is also the main source of GHG emissions. With the ratification of The Kyoto Protocol in 1997, this strategy offers opportunities for many countries to meet their carbon emission targets primarily through the three market-based mechanisms of emissions trading, also known as "the carbon market". Green building design, offers a better alternative to the conventional market of carbon trading (UNEP, 2004).

Heating, Ventilating, and Air Conditioning (HVAC) systems accounts for 40 to 60 percent of the energy used in commercial and residential buildings Chlorofluorocarbon (CFC) reduction in HVAC equipment. To minimize stratospheric Ozone depletion by zero, use of CFC-based refrigerants in the air conditioning systems is desirable. This will not only comply with the Montreal Protocol requirements, but also minimizing direct impact to stratospheric ozone depletion hence mitigating against climate change. It is desirable to consider designing buildings with no mechanical ventilation (air conditioning). Within the tropics, natural ventilation of buildings is highly possible through cross ventilation by taking advantage of cool breezes and fenestrations in the building (ASHRAE, 2008).

According to Yoders (2008), maximum energy savings can be achieved at no additional cost by pursuing passive design strategies for heating, cooling and ventilation such as; thermal mass cooling and heating by use of advanced building envelope, recessed fenestrations, use of overhangs, sun-shades and deciduous vegetation on the east- west facing fenestrations, that will shade the home in summer while still allowing light and heat during winter.

Optimizing energy performance and energy efficiency provides for a mechanism for assessing all the energy features of the proposed building design. It is desirable to use lighting with energy star rating, motion sensor controls on exterior and lobby lighting. Compact fluorescent bulbs and Light-Emitting Diodes (LEDs) are better lighting fixtures. LEDs provide illumination for twice as long as fluorescent bulbs and more than twenty times longer than incandescent. With optimized energy efficiency and performance, greater cuts in energy costs can be realized (Weil et al, 1998).

Green power is the current trend every green building design is striving to achieve. This focuses on ways to use renewable energy to offset non-renewable energy sources. With renewable energy such as; solar, wind and geothermal, green buildings can benefit from reduced energy consumption or qualify as energy neutral or a net-zero energy building. Excess energy, can also be purchased by third-party energy resellers or connected to the national grid and the money used to off-set other expenses on the building (McDonough and Gissen, 2002).

2.2.2.4. Materials and Resources

According to Kubba (2010), green materials come in many forms; recycled materials, reused materials, renewable materials or locally sourced materials. In the context of climate change, most green products are comparable to their non-green counterparts if not better in terms of quality, performance cost, durability and aesthetic appeal. When a building designed for a certain purpose ceases to serve the intended purpose with time, building adaptive re-use is one sustainable way of putting such buildings to proper use. and also help in maintenance of such buildings by preventing dilapidation and neglect.

A good building and construction method is that which produces less waste during the construction process. Proper construction waste management helps to avoid wastages on-site during the construction process. Modular/pre-fabricated construction methods are more sustainable ways to build compared to in-situ construction. Modular construction techniques help in saving on wastes on site, time and money during a construction process, since everything is made in the factory and brought on site for assembly (Yeang, 1995).

According to Edward and Joseph (2003), reuse of materials from demolished sites should be encouraged to reduce dumping and proliferation of dumpsites and landfills. On the overall, recycled materials are the most sustainable materials in the long-term since most of them use less energy, less material and require little time to produce.

This will encourage savings across the manufacturing chain; therefore reducing the embodied energy used in the production of the material. A building may appear to be green In terms of gadgetry, but when the ecological footprint of the materials is taken into consideration, that might not be the case (Figure 2.1). In this regard the ecological footprint is vital in determining the impact of a green building in mitigating against climate change.

Steel is sometimes more preferable than wood since it's more sustainable in the long run due to its high recyclability. In addition, reduction of embodied energy can be realized through use of rapidly renewable building materials and products such as bamboo. If wood is a must, especially for furniture and fittings, use wood from sustainably harvested forests. Similarly, flooring made from rapidly renewable materials such as cork, bamboo and linoleum with are more sustainable (Kubba (2010).

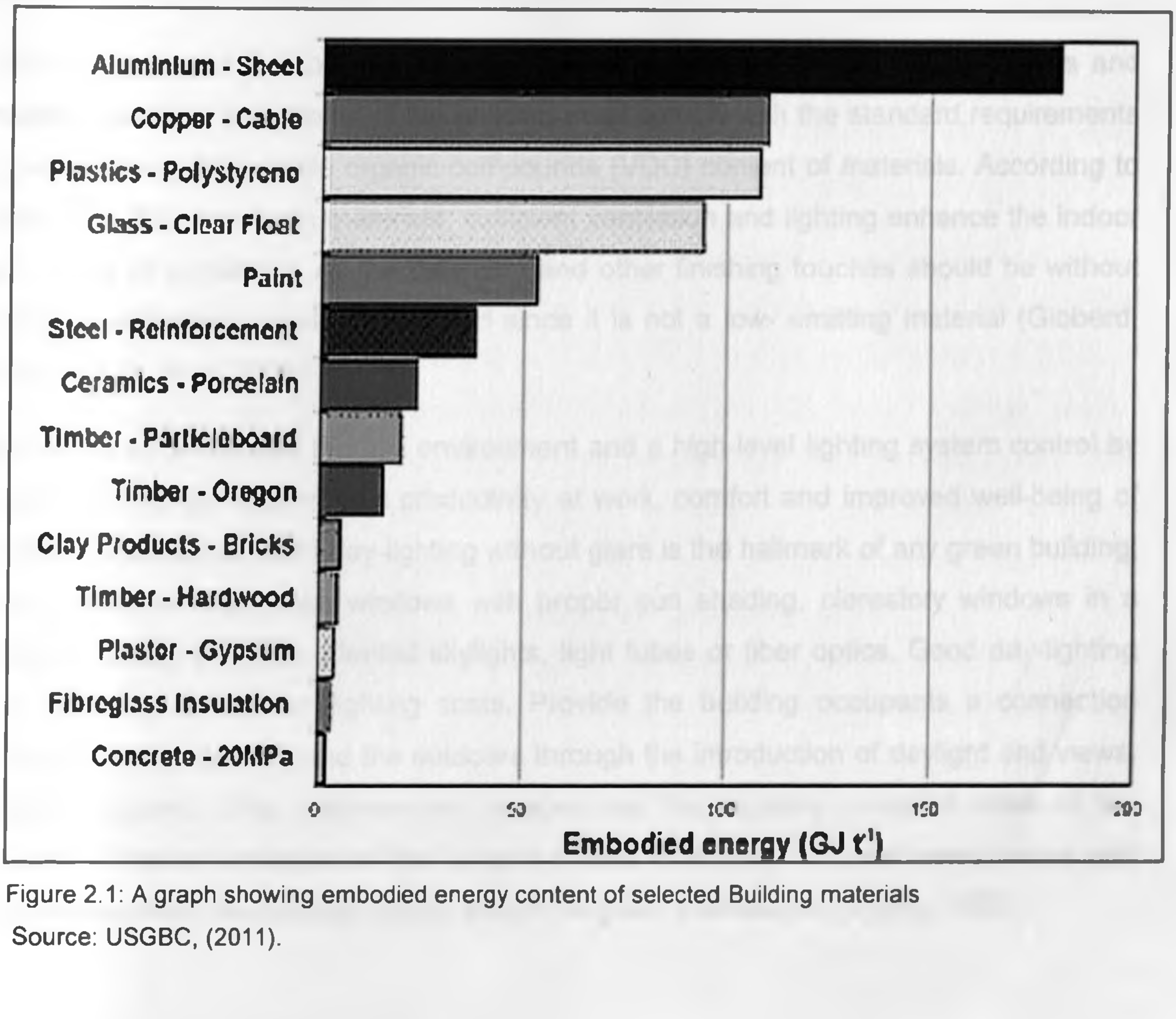


Figure 2.1: A graph showing embodied energy content of selected Building materials
Source: USGBC, (2011).

2.2.2.5. Indoor Environmental Quality

In green building design, Deasy (1985), indoor air quality is often cited as the second most important feature of a green building after energy use. The quality of the indoor environment plays a pivotal role in a person's health and the general output in a working environment. A healthier indoor environment in a building can be created through avoiding hazardous materials found in paint and other finishes, and potential impact they may have to the users.

It is vital to install smoke and carbon monoxide detectors in buildings, to detect any leakages of combustible and hazardous gases into habitable spaces within the building. To reduce occupant exposure to indoor pollutants, proper ventilation to the outside is essential. Appropriate distribution of space heating and cooling in the home to improve thermal comfort and energy performance should be provided to the building. Installing permanent monitoring systems to provide feedback on the performance of the ventilation system will enhance its safety (ASHRAE, 2008).

The finishes used in a building should be of low-emitting materials. All adhesives and sealants used on the interior of the building must comply with the standard requirements in reference to the volatile organic compounds (VOC) content of materials. According to Sandra (1986), non-toxic materials, sufficient ventilation and lighting enhance the indoor air quality of a building. All the cabinetry and other finishing touches should be without urea-formaldehyde should be avoided since it is not a low- emitting material (Gibberd, and Jeremy, et al. 2005)

Providing a comfortable thermal environment and a high-level lighting system control by individual occupants promotes productivity at work, comfort and improved well-being of building occupants. Good day-lighting without glare is the hallmark of any green building; this can come from large windows with proper sun shading, clerestory windows in a vaulted ceiling, properly oriented skylights, light tubes or fiber optics. Good day-lighting will also help to cut on lighting costs. Provide the building occupants a connection between indoor spaces and the outdoors through the introduction of daylight and views, balcony access, atria, galleries and arcades into the regularly occupied areas of the building. Proper orientation of the building to take advantage of good views, vistas and panoramas from the building should always be given precedence (Yeang, 1995).

2.2.3. Rating Systems for Sustainable Buildings

Green building rating tools use specific criterion compiled in guidelines and checklists with comprehensive measurable impacts on performance of buildings. These performance targets are organized into key performance areas such as: sustainable site development, human and environmental health, water and energy efficiency, materials and resources, indoor environmental quality, social aspects and economic quality. Each building project team chooses from this menu of "credits" (key performance areas) and decides which are most appropriate for particular building circumstances in order to achieve enough points to receive a rating. (Macaluso, 2009)

The rating systems were developed for different uses of buildings. Depending on the method used, individual points are either added up or initially weighted and then summed up to obtain the final score. Based on the weighted score, the numbers of points are ranked on the rating scale which is divided into different levels. The higher the number of points the better the certification .This research borrows from the existing examples of rating systems globally and proposing one that is tailor-made to suit the Kenyan context. For the Kenyan case, out of the five key performance areas in buildings, energy and water efficiency and materials and resources will be given more emphasis hence more credits when developing the rating system (Lee and Burnett, 2008).

Different countries have developed their own rating systems for sustainable buildings. Some systems are more popular than others and therefore have been used to certify more buildings than others. Leadership in Energy and Environmental Design (LEED), a voluntary certification agency developed in 1999 by the U.S. Green Building Council (USGBC).The rating and points-based system stretches across six categories. Each category has sub-categories that are assigned a number of points, adding up to an overall possible score of 69 points. Building Research Establishments Environmental Assessment Method (BREEAM) developed in the United Kingdom in 1990. BREEAM covers a range of building types including: offices, homes, industrial units, retail units, and schools. The overall building performance is awarded a "Pass", "Good", "Very Good" or "Excellent" rating, based on the following categories: Management, Health & Wellbeing, Energy, Transport, Water, Materials, Ecology and Pollution (Mitchell 2009).

Green Star is a rating tool was first developed by Australia Building Research Establishment in 2003.It was then taken up and is currently operated by the non-profit Green Building Council of Australia (GBCA). Green Star is based on BREEAM, as well drawing on operational elements of the LEED system which is tailored made to suit to Australian climatic conditions and local building standards and regulations. New Zealand and South Africa also use the "Green Star", rating system run by respective Green Building Councils (Fowler and Rauc, 2006)

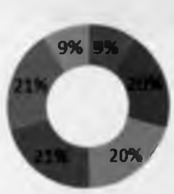
System (County of Origin)	DGNB (Germany)	BREEAM (Great Britain)	LEED (USA)	Green Star (Australia)
Initiation	2007	1990	1999	2003
Key Environmental Aspects of Assessment	Ecological Quality Economical Quality Social Quality Technical Quality Process Quality Site Quality	Management Health & Well-being Energy Water Material Site Ecology Pollution Transport Land consumption	Sustainable Sites Water Efficiency Energy & Atmosphere Material & Resources Indoor Air Quality Innovation & Design	Management Indoor Comfort Energy Transport Water Material Land & Ecology Emissions Innovations
Building Type and Versions	Offices Existing Buildings Retail Industrial Portfolios Schools	Courts, Eco Homes, Education, Industrial, Healthcare, Multi-Residential, Offices, Prisons, Retail	New Construction, Existing Buildings, Commercial Interiors, Core and Shell, Homes, Neighborhood Development, School, Retail	Office-Existing Buildings Office-Interior Design Office-Design
Level of Certification	Bronze Silver Gold	Pass Good Very good Excellent Outstanding	Silver (33–38 points) Gold(39–51 points) Platinum (52–69 points	1star - Minimum Practice 2stars - Average Practice 3stars - Good Practice 4stars - Best Practice 5stars - Australian Excellence 6stars- World Leadership
Category Weighting (%)	Ecological Quality Economical Quality Social Quality Technical Quality Process Quality Site Quality 	- Management - Health & Well-being - Energy - Water - Material - Site Ecology - Pollution - Transport - Land consumption 	- Sustainable Sites - Water Efficiency - Energy & Atmosphere - Material & Resources - Indoor Air Quality - Innovation & Design 	Management Indoor Environmental Quality Energy Transport Water Materials Land Use and Ecology Emissions 

Table 2.1: A table showing the Comparison of Different Rating Systems for Sustainable buildings

Source: Bauer, (2007)

2.2.4.Case Study: The New Headquarters of United Nations Environment Programmee (UNEP) and United Nations Human Settlements Programme (UN-HABITAT),in Gigiri-Nairobi.

Architectural design

According to Stephen Stannah, Chief Facilities, UNON, The new office facility which houses the headquarters of both the United Nations Environment Programme (UNEP) and the United Nations Human Settlements Programme (UN-HABITAT), takes environmental sustainability to a new level and may well be a first in sub-Saharan Africa. The new Complex is a set of four buildings, linked by airy walkways, flooded with natural light, and with green areas individually landscaped and themed, designed to accommodate 1,200 staff.

According to Architect Woods, Nairobi temperatures are typically in the mid-20s Celsius and the building uses this benevolent climate to maximum effect, with natural heating and cooling, abundant natural light, and solar energy. One of the great benefits of the Nairobi climate is that, with good design, there is no need for either heating or cooling in buildings. Since air conditioning and central heating are both expensive huge consumers of energy and emitters of GHGs, this is a great bonus for energy neutral buildings. Construction used as many renewable and recycled materials as possible to minimize energy use and hazards to human health, and local materials were selected when available in order to avoid excessive GHG emissions.

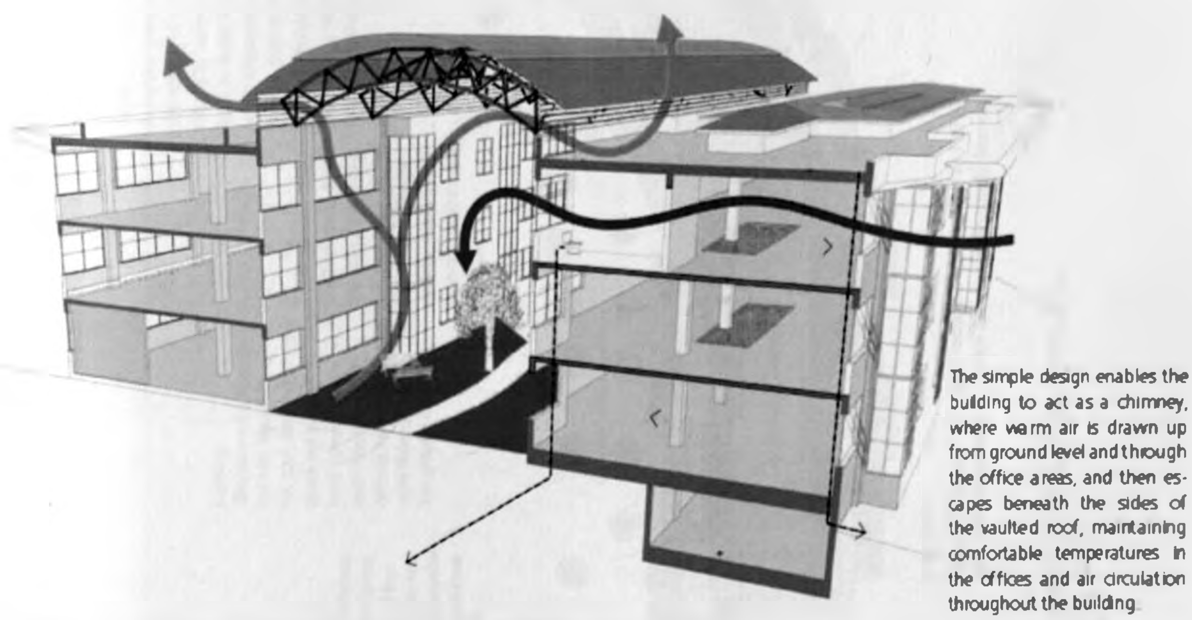


Figure 2.2: Environmental Features of the Building at a Glance

Source: UNEP, (2011)

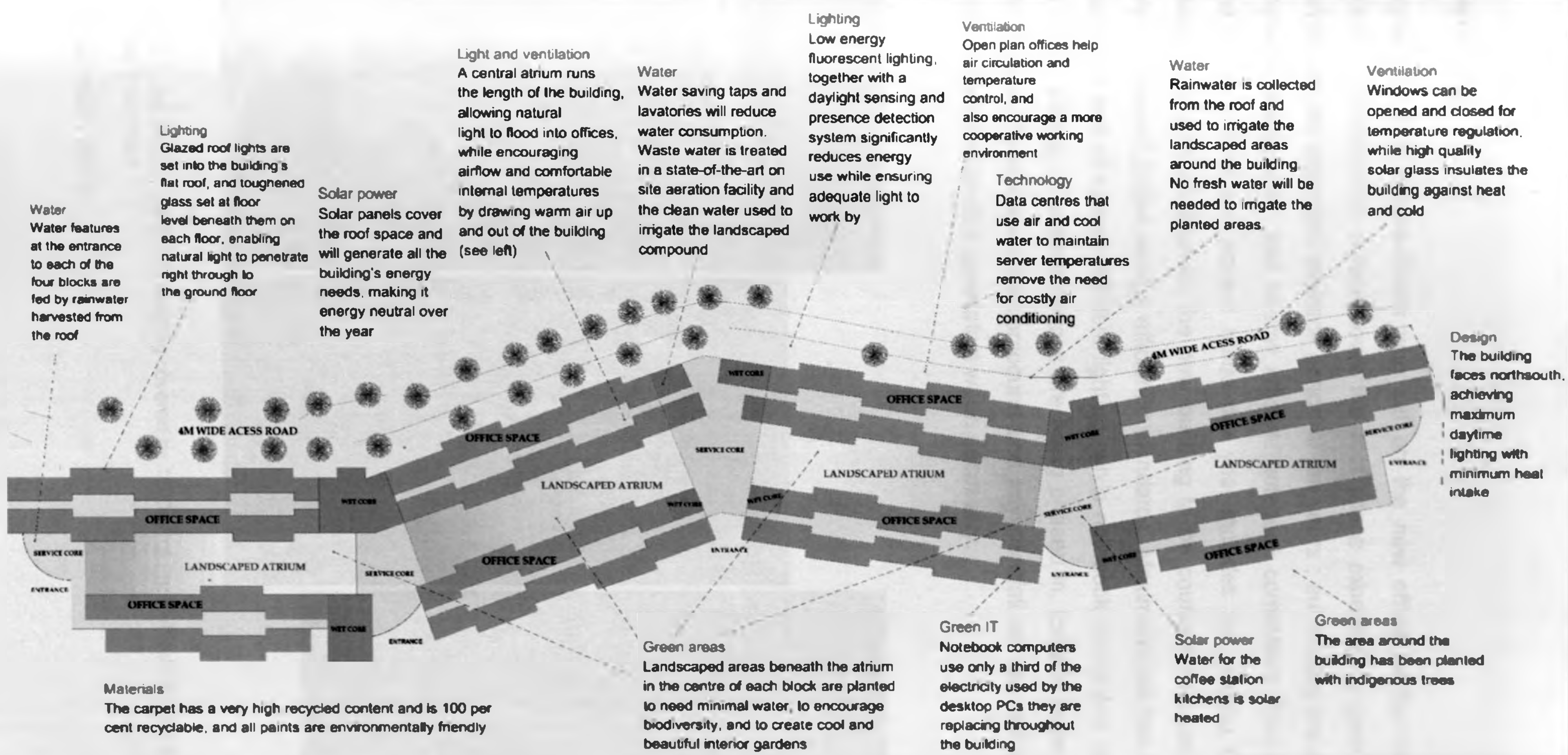


Figure 2.3: Interactive floor plan of the UNEP Building
Source: UNEP, (2011)
Scale 1:750

Green Energy

According to Neil Reece-Evans who sat on the new office facility committee, over 6000m^2 of photovoltaic panels cover the roof space expected to generate over 750 000kWh with an expected payback period of ten years ; automated low energy lighting illuminates workspaces, and energy efficient notebook computers. This new building's target of 42.5 kWh per square metre per year includes the cooling required by IT infrastructure, and so enables the new building to be counted amongst those ranked highly in terms of global energy efficiency standards. Maximum use has been made of natural light and of energy efficient lighting, while notebook computers that use only a third of the energy of older desktops are being phased in. Excess solar power can be used by other buildings on the compound and any shortfall will be met by the national power supply and standby generators when necessary.

Plate 2.1: the Roof of the Entire Building covered by 1600m^2 of Photovoltaic Panels and Solar Water Heating Equipment

Source: UNEP, (2011)

Water Efficiency

With increased staff in the new building, that meant that reducing water use, increasing water efficiency and boosting water recycling were of essence. All rainwater is harvested from the roof of the new building, a measure that could yield around 7.5 million litres of water in an average rainfall year. Rainwater is collected from the roofs to feed the fountains and ponds at the four entrances, and sewage is treated in a state-of-the-art aeration system and recycled to irrigate the beautifully landscaped compound. All sewage and wastewater goes to the new state-of-the-art sewage processing plant where it is purified by aeration and emerges clean, ready to join the rainwater in the lagoon. The harvested and recycled water is used to irrigate the landscaped areas around the new building, so no fresh water is required to maintain the gardens and trees that make the new office complex so beautiful and sustain so much biodiversity. The building boasts of one of the best and most efficient plumbing fittings. All lavatories are dual flush, saving between six and nine litres per flush on older models, and all taps are fitted with aerators that reduce consumption by around 10 per cent. For ease of maintenance all plumbing is accessible via ducts in each of the wet core areas.

Plate 2.2: Water ponds and fountains, rain catchment roof cover and the new state-of-the-art sewage processing plant

Source: UNEP, (2011)

Landscaping

Without compromising the working environment, the new building and its environmentally responsible features are acknowledged to be a huge enhancement of the surroundings and comfort for the staff. According to Bruce Hobson, the landscape designer commissioned to see that occupants of the new green building look out onto green views." The landscaping of the new building provides a terrific opportunity not only to create a stunning environment, but also to show how beautiful and creative gardens can be created and maintained using minimum amounts of water." The building was deliberately sited in such a way that the maximum number of existing trees could be preserved, and those few — mostly exotic species — that had to be removed were replaced elsewhere in the compound with indigenous varieties which are more drought-resistant and encourage birds and other smaller wildlife. The landscaped areas within the building, beneath the central atrium that runs the length of the four blocks, are particularly unique. Each of the four interior gardens is planted to represent a different climatic zone of Kenya. Each garden is watered by an automated irrigation system that can be programmed to give the appropriate amount of moisture for each area, and all are frugal in their water needs.

Plate 2.3: Well Landscaped Atrium and Exteriors

Source: UNEP, (2011)

Lighting

The new building was planned to make maximum use of natural light, simultaneously reducing costs and energy consumption, while creating man attractive working environment. The three storey building has a central atrium running throughout, covered by a barrel vaulted translucent roof. According to Peter Grayson, the electrical engineer, Nairobi has a high natural light intensity as there are overcast days of cloud and rain, so it is not possible to rely on natural light alone. Energy efficiency has been enhanced by the use of efficient fluorescent luminaires and combined with daylight sensing and presence detection controller system that automatically dims or increases lighting as needed, and switches lights off completely if it detects no-one is in the sensor area. The building's open office layouts not only encourage a cooperative working atmosphere, but also greatly assist in airflow and temperature regulation. All Windows are operable, and are fitted with solar glass to prevent internal heating from sunlight, but to retain heat in colder weather.

Plate 2.4: Well Lit Glass-Covered Atriums and Glazed facades to enhance Day lighting

Source: UNEP, (2011)

Green IT

According to Akimasa Nishizono, a member of the information and communication technology team, the most obvious IT difference in the new building is the shift from desktop to notebook computers, yielding an immediate energy saving of around two thirds. Working from United Nations best practice guidelines on notebook computers, the green IT team identified a supplier that could offer local maintenance and warranties, together with an intelligent A/C adaptor which, unlike many others, reduces energy consumption to almost nil when machines are off or in standby mode. Computers account for only a small proportion of total IT energy consumption, so it's vital to consider printers, copiers, telephones, and particularly servers, which consume large amounts of energy and need to be kept cool.

Some way into the project it became clear that the computer server rooms would need to be cooled by power-hungry air conditioners, making it difficult to achieve energy neutrality. A study led to the decision to procure a highly efficient IT Pre-Assembled Component (ITPAC) external server room (see below). ITPACs use fans to create negative pressure, drawing air through the container to cool equipment. If the air is too warm, it is drawn through cool water to reduce its temperature, and the water is then recycled. The expected energy savings are such that the substantial cost of purchase can be recouped in less than five years through savings in electricity bills.

Plate 2.5: Green IT Equipment

Source: UNEP, (2011)

2.2.5. Building code : The local government adoptive by-laws and building order of 1968.

Physical development planning is not a prerequisite of any building construction project in Kenya. In this regard, building and construction sector has been proceeding without the appropriate planning and building laws and regulations. The current building code and By-laws of 1968 are outdated and ineffective and thus have been an impediment to delivery of a sustainable building and construction sector. There is need to review the existing policies, laws and regulations that guide the planning and building industry. This research identified the following gaps to be addressed.

1. The absence of a national land use and urban policy has resulted in haphazard developments that are incompatible and conflicting and are poorly served with infrastructural services and with developments.

2. The current building code is limiting the choice of building materials to be used within the municipal authorities hence making construction expensive. The new planning and building regulations should broaden the range of acceptable construction materials beyond brick and mortar. Locally available materials and latest building technologies could help offer faster and cheaper sustainable construction technology.

3. The regulations should help in the design of buildings that meet specific needs to cater for disabled people and ensure that the primary function for which the building was designed is observed. Ramps elevators, sidewalks, wheelchairs and corridors should be adequately designed to accommodate the said needs.

4. The new laws should aims at integrating environmental aspects in the national development planning process. The Environment Management and Coordination Act should be reviewed to give comprehensive guidelines for achieving sustainable development with regard to green building design.

5. The harmonization of all policies, laws and regulations that govern the planning and building sector should be emphasized, through enactment of relevant legislation and creation of requisite oversight authority to coordinate the anticipated reforms.

2.3. Conceptual Framework

The arrows indicate the inter relationships and comparisons on the impact of climate change and how green buildings can be used a s a measure to adopt and mitigate against climate change. The five key performance areas in green buildings namely: sustainable site development, Water and energy efficiency, indoor environment quality, resources and materials are important in cutting down the amount of greenhouse gases emitted by buildings, in order to achieve sustainable development.

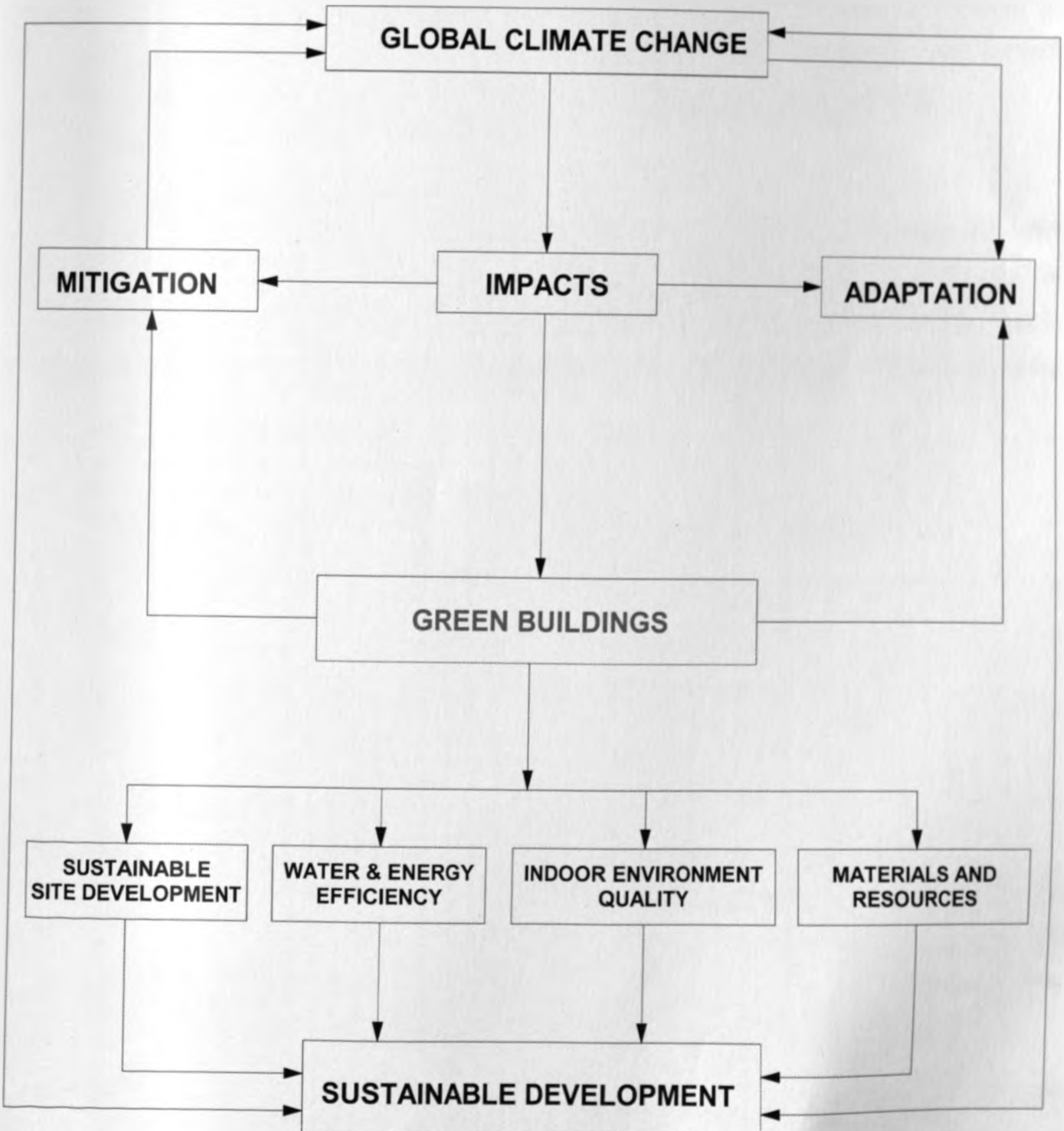


Figure 2.4: Conceptual Framework

Source: Research, (2012).

CHAPTER THREE

3.0. METHODOLOGY

3.1. Research Design

This research carried out a field study on the principles of green building design. It was informed by existing examples of best practice(s) in green building design and green building rating systems which were tailor-made to suit the Kenyan context. The study collected data on existing buildings within the area of study to ascertain whether the buildings are green or not. Finally, this research is geared towards forming a model guideline that can be used to design and rate future green buildings in Kenya.

3.2. Data Types and Sources

Primary data was collected from the field after carrying out a field survey administered by the use of questionnaires. In areas where specialized information was required key informants were used. Personal observations and use of photographs were also used to collect additional information. The following key performance areas in buildings formed the main variables of the study;

1. Sustainable Site Development
2. Energy Efficiency
3. Water Efficiency
4. Indoor Environmental Quality
5. Resources and Materials

3.3. Sampling Frame

The sample frame comprised of only high-rise office buildings of not less than three storey and not more than fifteen storey within zone 3 of Westlands Area of Nairobi CBD. Zone 3 is delineated by Chiromo Road, Museum Hill Road, Ojijo Road, Parklands Road, Ring Road Parklands, joining Waiyaki way at the Pio Gama Pinto Road.

Through a physical count of all office buildings within the area of study, 51 office buildings fell within the sample frame. However, not all the buildings were used in the research because of several constraints;

Four office buildings were inaccessible because of security reasons, 9 office buildings were still under construction and 5 respondents were uncooperative. The remaining 33 buildings were used in the study, which translates to 64% of the buildings within the sample frame of the study area. In a quantitative research, a sample of 30 respondents is considered representative, the researcher therefore considered the 33 buildings representative enough and all the 33 buildings were used in the study.

3.4. Data Collection

Questionnaires formed the main instrument for data collection (Appendix III). The questionnaire used was structured and non-disguised. The respondents were guided by the closed-ended questions categorized in the five main categories as earlier indicated. The respondents were expected to select from a fixed list of replies, and choose any one of the options given or multiple options. This was to facilitate coding and also help in quantifying the answers to the questions based on the checklist that was prepared for data analysis.

The property agents and property managers for the respective buildings were used as the respondents. In cases where specialized information was required and the respondents were not competent enough to respond, key informants were used to get the required information. Personal observations and photographs were also used to aid in data collection especially of materials and finishes used on the buildings.

Thirty three questionnaires were administered during data collection. The data obtained from questionnaires was matched-up with the data score sheet, weighted and given a score. The total score in the five key building performance areas was used to give a total weighted score of the building.

3.5. Data Processing Analysis

The valid returns were weighted and tallied into a data entry score sheet (Appendix IV). Each question on the questionnaire was cross matched with a corresponding score on the data score sheet to award a score based on the maximum and minimum available credit for each building element. The scores on each element on every variable were computed to give a weighted score for each category.

The processed data was analysed using Statistical Package for Social Scientists (SPSS) software as the main analysis platform. The data collected was in ordinal form with multiple variables with a maximum of six variables per question. Descriptive techniques such as, Pie charts, frequency tables and bar graphs were used to analyse the data. To establish if there is any significant difference in the green buildings in Nairobi, Chi-Square (X^2) was used to test the research hypotheses to establish if there is any significant difference among the green buildings in the area of study (Table 3.2). The 33 buildings under study were given a rating based on a weighted multi-varied credit score on five key performance areas. Frequency tables (Table 3.1) scores sheet were used to award each building a rating.

WEIGHTED SCORE	GREEN STAR RATING
71-84	5 STAR
54-71	4 STAR
36-53	3 STAR
18-35	2 STAR
1-17	1 STAR

Table 3.1: A table showing score rating frequency of the buildings under study
Source: Research, (2012).

The various categories investigated for building performance during the study

CATEGORY	TOTAL SCORE
1. Sustainable Site Development	**14 Points**
▪ Site Selection and Development	
▪ Building Shape and Orientation	
▪ Landscape Design	
▪ Heat Island Effect	
2. Water Efficiency	**14 Points**
▪ Water Efficient Landscaping	
▪ Innovative Wastewater Technologies	
▪ Water-use Reduction	
3. Energy Efficiency	**25 Points**
▪ Energy Conservation	
▪ Green power	
4. Indoor Environment Quality	**12 Points**
▪ Thermal comfort	
▪ Day lighting and Views	
▪ Indoor Air Quality	
5. Resources and Materials	**19 Points**
▪ Sustainable Materials	
▪ Material Embodied Energy and carbon footprint	
▪ Sustainable Waste Management	
▪ Architectural Design and Innovation	
WEIGHTED BUILDING SCORE	**84 POINTS**

3.4.1 Chi Square test

After data analysis, the results obtained were used to carry out a non-parametric test using Chi-Square (X^2) to test the hypothesis of the study.

Table 3.2: Contingency table for nine selected buildings for the Chi Square Test

Environmental Element	Sustainable Site Development		Water Efficiency		Energy Efficiency		Indoor Environment Quality		Materials and Resources		Weighted Score	Green Star Rating
	(O)	(E)	(O)	(E)	(O)	(O)	(O)	(E)	(O)	(E)		
Fedha Plaza	2	1.43	0.5	1.91	4	4.57	4	3.84	4.5	3.84	**15**	**1star**
Mpaka House	1.5	1.62	3	2.16	3	5.17	4.5	4.35	5	4.35	**17**	**1star**
Vision Plaza	4	2.00	3	2.67	2.5	6.39	5.5	5.38	6	5.38	**21**	**2star**
Unga House	2	2.00	3	2.67	6	6.39	5.5	5.38	6	5.38	**21**	**2star**
Soin Arcade	3	2.96	3.5	3.92	8.5	9.44	7.5	7.94	8.5	7.94	**31**	**2star**
Apic Centre	2.5	2.96	2.5	3.92	11	9.44	7	7.94	8	7.94	**31**	**2star**
Brick court	2	3.53	2.5	4.70	11	11.26	10	9.47	11.5	9.47	**37**	**3star**
Eden Square	6	4.01	3.5	5.33	14.5	12.79	11	10.75	7	10.75	**42**	**3star**
Stanchart Hse.	2.5	4.10	10	5.46	15	13.10	8.5	11.01	7	11.01	**43**	**3star**
Total	**23.7**	**24.61**	**31.5**	**32.74**	**75.5**	**78.55**	**63.5**	**66.06**	**63.5**	**66.06**	**248**	

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

$$\chi^2 = \sum \frac{(23.7 - 24.61)^2}{24.61} + \frac{(31.5 - 32.74)^2}{32.74} + \frac{(75.5 - 78.55)^2}{78.55} + \frac{(63.5 - 66.06)^2}{66.06} + \frac{(63.5 - 66.06)^2}{66.06}$$

$$\chi^2 = 0.03 + 0.05 + 0.12 + 0.01 + 0.01$$

$$\chi^2 = 0.22$$

At 40 degrees of freedom (d.f) and at the critical value at 0.05 confidence levels, the calculated value is not greater than the critical value and therefore it can be concluded that there is no significant difference among the green buildings in the area of study.

3.5. Scope and Limitation

This research was limited to an investigative study on green buildings in Nairobi and their impact on climate change mitigation.

The scope of the building type was limited to high-rise office buildings only, of not less than three storey and not more than fifteen storey. This bias in the height of buildings was necessitated by wind dynamics in terms of drag for buildings below three storey and turbulence for buildings with more than fifteen storey.

The building sector is very wide; the study area was narrowed down to zone 3 of Westlands of Nairobi CBD. This area has been zoned for office and commercial use. It is delineated by Chiromo Road, Museum Hill Road, Ojijo Road, Parklands Road, Ring Road Parklands, joining Waiyaki way at the Pio Gama Pinto Street (Figure 1.4).

CHAPTER FOUR

4.0. RESULTS AND DISCUSSIONS

4.1 Sustainable Site Development

4.1.1. Site selection and development

All the respondents were asked if their buildings were on a reclaimed wasteland, none of the buildings were. Property developers should endeavour to create more land for urbanization by reclaiming wastelands such as dumpsites, abandoned quarries and other derelict lands. There also should be reduced site disturbance during and after construction to preserve the existing biodiversity. A comprehensive environmental impact assessment and audit should be carried out to safeguard against negative environmental impacts.

4.1.2. Building Shape and Orientation

Most old buildings within the area of study were found to have orthogonal shapes. The newer buildings were more aesthetically appealing with more ornate shapes and form. The Citadel Building along Muthithi Road has a good aesthetic appeal with an elaborate design from the de-constructivist movement. Having attractive buildings along a street is more desirable to help reduce sight pollution and urban blight. Two thirds of the buildings surveyed were found to have a more north-south orientation (Table 4.1), where little or no openings were located on the east-west facing facades to avoid direct solar gain. Correct building orientation with the longest facades along the east-west axis, is critical in the reduction of energy consumption and creating a more conducive indoor working environment, hence less need for air conditioning which has adverse effects on human health and the environment.

	Frequency	Percent
North- South	22	67
East- West	11	33
Total	33	100

Table 4.1: Orientation of buildings in the study area
Source: Research, (2012)

Plate 4.1: Aesthetically appealing Citadel Building along Muthithi Road

Source: Research, (2012)

4.1.3. Landscape Design

Nearly all buildings (97%) within the area of study did not harvest storm water for on-site re-use (Table 4.2). Most buildings within the area of study need to adopt a proper storm water design to harvest storm water and minimize surface. Increasing the time lag for surface run-off by landscaping allows for maximum ground seepage to naturally recharge groundwater. The storm water can be used for non-drinking purposes such as; irrigation of plants, cleaning of pavements and car washing.

	Frequency	Percent
No	32	97
Yes	1	3
Total	**33**	**100**

Table 4.2: Storm water harvesting by buildings for re-use
Source: Research, (2012)

4.2. Heat Island Effect

Eighty eight percent of buildings within the study area had no trees planted on site (Table 4.3). This was mainly dictated by the insufficient setback/ building line from the access road/street. The existing building is outdated and limiting, it should be reviewed to incorporate principles of green building design. Only 12 % of buildings had planted trees on site. Trees and vegetation on site can be used to directly shade buildings hence decrease the demand for air conditioning.

Apart from reducing energy demand and GHG emissions, they help to improve air quality by removing air pollutants, storage and sequestration of carbon dioxide. In addition, trees enhance storm water management and ground water quality by reducing surface runoff, augment seepage and filtering of rainwater. Concrete blocks were used to pave 91% of the buildings surveyed; this was mainly influenced by the current building trends. Asphalt paving was used by 7% of the buildings, predominantly in the older buildings. More sustainable paving surfaces like grass blocks should be encouraged.

	Frequency	Percent
No	27	82
Yes	6	18
Total	**33**	**100**

Table 4.3: Orientation of buildings in the study area
Source: Research, (2012)

Plate 4.2: Corrugated Iron Sheet Roofing on Centro House along Ring Road Parklands

Source: Research, (2012)

The scope of buildings under study were between three and fifteen stories, flat roofs finished in asphalt felt or shingles was the most popular roof type (Figure 4.1). Three quarters of the buildings had flat roofs finished in asphalt. Dark coloured roof finishes such as asphalt contribute negatively to the environment by increasing the urban heat island hence aggravating global warming. A third of the buildings within the study area were roofed in galvanized corrugated iron (GCI) sheets. Galvanized corrugated iron sheets are good in reducing the heat island effect because of their high albedo. Therefore materials with high albedo should be more preferred for roofing.

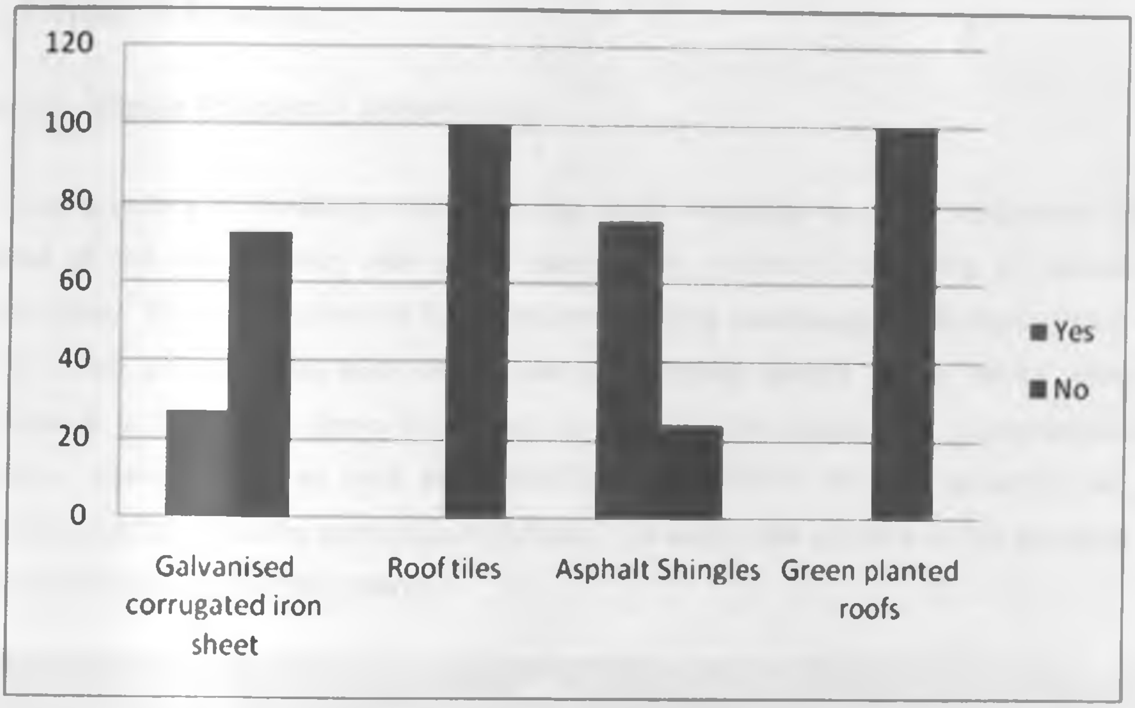


Figure 4.1: A graph showing the distribution of roof types used on the buildings studied

Source: Research, (2012)

Green roofs or "roof gardens" offer a more sustainable option, especially for high rise buildings. However, green roofs are not very popular for the tropical climate since they are prone to leakages (Figure 4.1). Green roofs insulate buildings by removing heat from the air through evapo-transpiration, hence reducing energy needed to provide cooling and heating in buildings through air conditioning. By lowering the air conditioning demand in office buildings, green roofs also decrease the production of associated air pollutants and GHG emissions through dry deposition and carbon sequestration and storage. Green roofs can also reduce and slow storm water runoff in the urban environment; filter pollutants from rainwater, improve aesthetic value of buildings and create a habitat for many species.

4.2 Water Efficiency

4.2.1. Water Efficient Landscaping

Three quarters of buildings surveyed had done landscaping using indigenous plants. Most of the landscaping was albeit elementary, limited to planning of flowers and shrubbery. The landscaping of Eden Square Building was exceptionally done (Plate 4.3). The three office blocks surround a well landscaped central piazza which forms the entrance to the offices above a covered car parking. The piazza itself is landscaped with lawns, ponds, pools as well as a terrace for people to sit out, generally an area conductive to a relaxed working environment. Seventy nine percent of the buildings with landscaping irrigated their plants.

Plate 4.3: A view of the well landscaped Piazza of the Eden Square building along Chiromo Road

Source: Research, (2012)

4.2.2. Innovative Wastewater Technologies

Adopting innovative wastewater technologies within buildings helps to conserve water usage. Only the new Standard Chartered Building along Chiromo Road recycles both grey and black water from its building. Ninety seven percent of the buildings surveyed neither recycle nor re-use wastewater. Onsite wastewater treatment systems are the most sustainable options to manage waste water from buildings. These systems encourage recycling and reuse of the water on site, they reduce water demand by buildings, and more importantly reduce the pressure on urban sewerage systems which are the main sources of methane and nitrous oxide gases.

4.2.3. Water-use Reduction Technologies

Water-use reduction technologies help to reduce water consumption by buildings. Alternative sources of water ensure reliability and continuous water supply. Unfortunately, three quarters of the buildings surveyed relied on water from NW&SC, 21 % used borehole water (Figure 4.2). Only one building harvested rain water and recycled both grey and black waste water on site. The water is collected and stored in an underground tank; from there, the water is treated and pumped to a domestic water storage tank for non-drinking purposes such as cleaning of pavements and irrigation of plants.

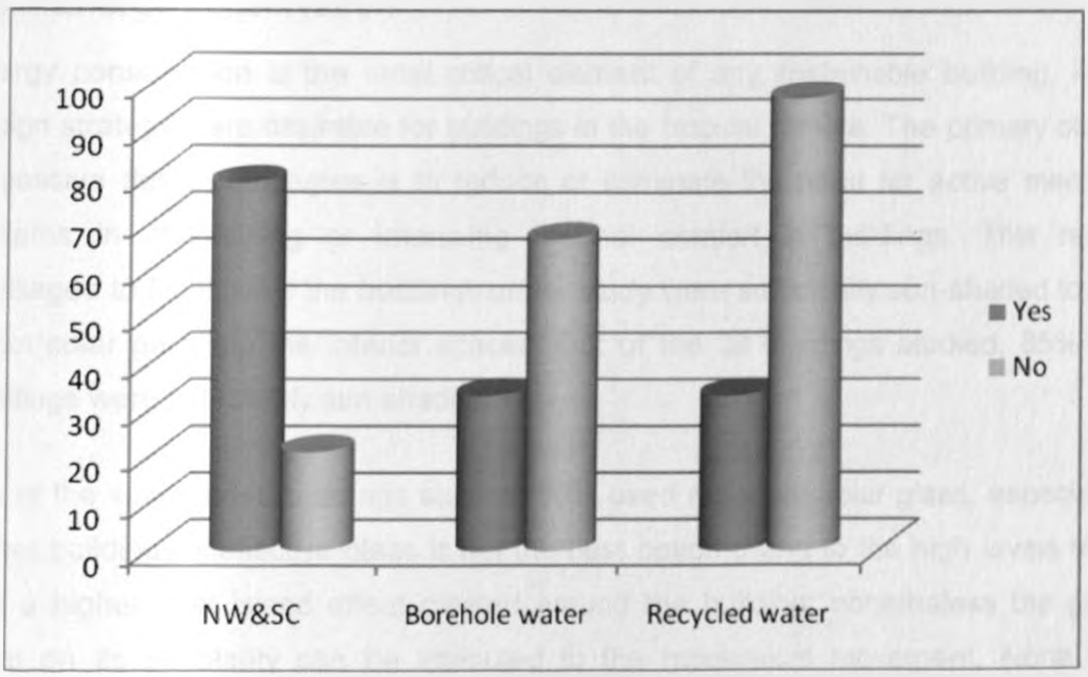


Figure 4.2: A graph showing the type of water sources by the buildings studied

Source: Research, (2012)

Other than the water source, innovative technologies play an important role in enhancing water efficiency. More than three quarters of the buildings used press taps to control water use and misuse (Table 4.3). In this case, the probability of leaving running taps after use is greatly reduced hence conserving water. Woodvale Groove Centre on Woodvale lane and the new Standard Chartered Building along Chiromo Road use dual flush toilets to conserve water.

Technology Type	Yes		No	
	Frequency	Percent	Frequency	Percent
Push taps	16	49	17	52
Dual-flush toilets	2	6	31	94
Waterless urinals	1	3	32	97
Infrared-flush sensors	28	85	8	15

Table 4.3: Water-use reduction technologies used in the buildings

Source: Research, (2012)

4.3. Energy Efficiency

4.3.1. Energy Conservation

Energy conservation is the most critical element of any sustainable building. Passive design strategies are desirable for buildings in the tropical climate. The primary objective of passive design strategies is to reduce or eliminate the need for active mechanical systems in maintaining or improving thermal comfort in buildings. This research envisaged to establish if the buildings under study were sufficiently sun-shaded to cut off direct solar gain into the interior spaces. Out of the 33 buildings studied, 85% of the buildings were sufficiently sun shaded.

Out of the sun-shaded buildings studied, 50% used reflective solar glass, especially the newer buildings. Reflective glass is not the best option owing to the high levels of glare and a higher heat island effect created around the building; nonetheless the growing trend on its popularity can be attributed to the modernism movement. None of the buildings used absorbing solar glass as a sun shading element. Concrete and aluminum fins were very popular as sun-shading elements for tropical climate (Figure 4.3).

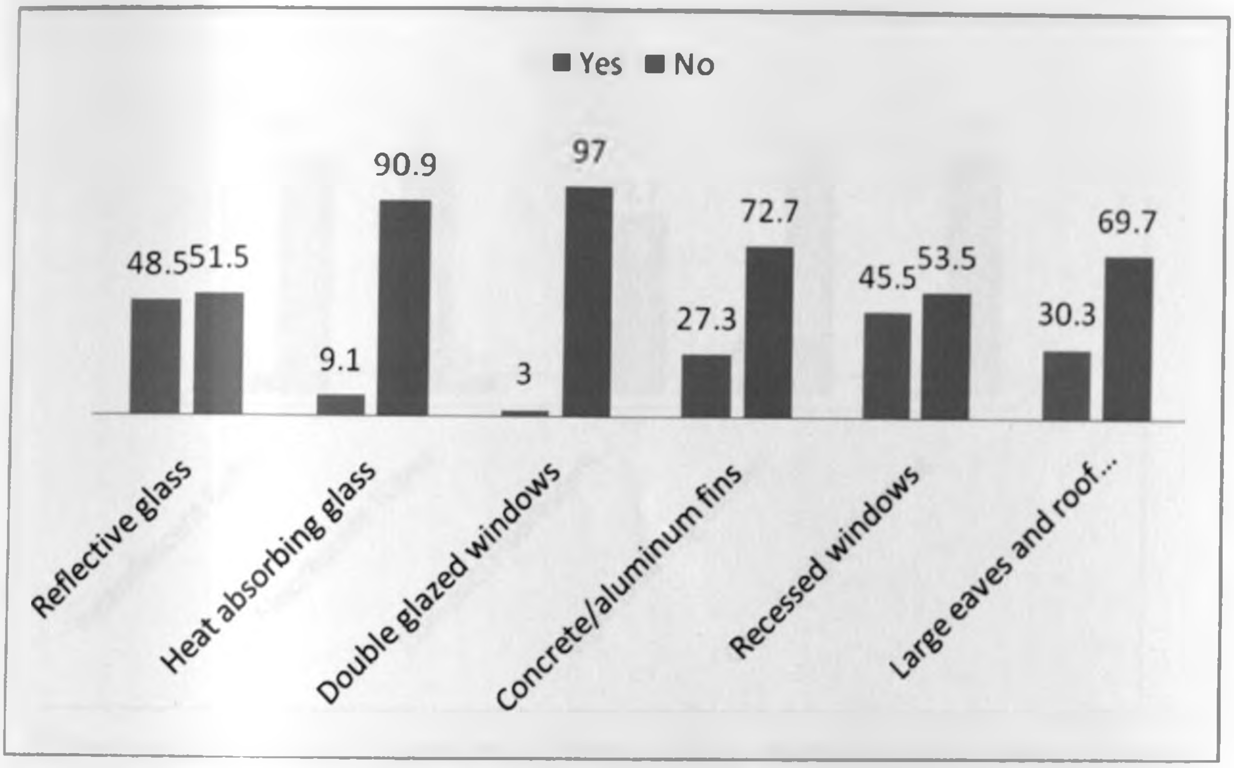


Figure 4.3: A graph showing the distribution of type of sun shading devices used on the buildings studied

Source: Research, (2012)

With proper design in terms of size and positioning, sun shading elements are the most desirable and cost effective way to cut off direct solar gain into buildings within the tropics. Large eaves and overhangs work in more less the same way as shading fins. The type of a lighting fixture is also fundamental to energy use and consumption within a building. A sustainable way to light a building is to use a fixture that is compact, consumes less energy (energy saving) and has a long life. Due to increased awareness and need to cut on energy costs, 91% of the buildings used fluorescent tubes and 6% used the compact type (Figure 4.4). Incandescent bulbs are no longer a preferable option due to their warm light, heat emitting, and non-durable qualities and hence none of the buildings preferred them. The LED lights are gaining popularity with the newer buildings adopting them due to their sustainability features of long life small size and low energy rating. The new Standard Chartered Building along Chiromo Road has extensively used the LED lights.

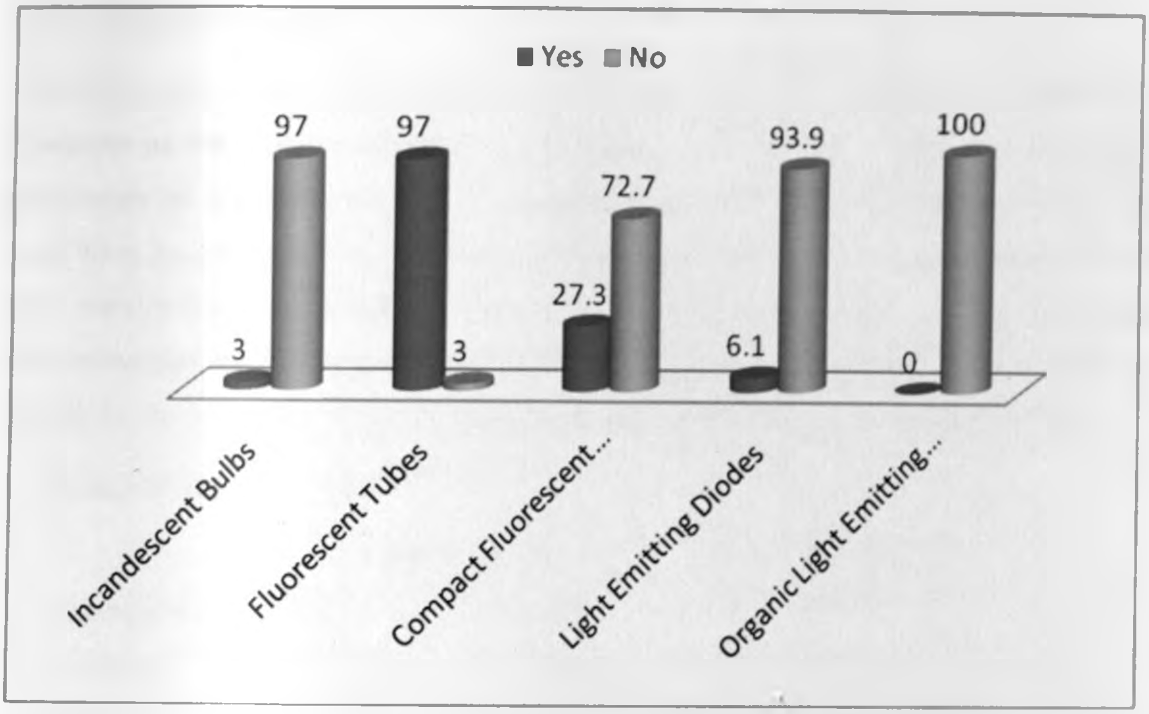


Figure 4.4: A graph showing the distribution of type of Lighting Fixtures used on the buildings studied

Source: Researcher, (2011)

The type of lighting switch complements the lighting fixture used in a building. Nearly all buildings studied used wall switches as a medium of lighting control (Table 4.4). The new Parklands Plaza along Chiromo Lane used LDR (Light Dependent Resistor) switches for their outdoor lighting which automatically switches the light on and off at dusk and dawn respectively to help in energy efficiency and conservation. One building used infrared sensors and light dimmers to control all the lights within the building. This works on a detection controller system that automatically dims or increases lighting as needed, and switches lights off completely if it detects no-one within the sensor area. With no light switches in office areas, the risk of leaving lights on overnight is eliminated hence conserving energy.

Type of switches	Yes		No	
	Frequency	Percent	Frequency	Percent
Wall switches	31	94	2	6
Light Dependent Resistor	3	9	30	91
Infra-red Sensors	2	6	31	94

Table 4.4: A table showing the types of switches used by buildings

Source: Research, (2012)

4.3.2. Green Energy

This is an area where most buildings performed poorly. All the buildings surveyed used electricity as their main source of energy (Table 4.5). A quarter of the buildings relied on generators as a backup source of energy during power outages. None of the buildings used wind as their main or alternative source of energy. Only one building had embraced solar energy for heating water in the kitchens and changing rooms. Overdependence on non-renewable sources of energy means most of the buildings surveyed are contributing greatly to the emission of GHG hence aggravating the effects of climate change.

Energy Source	Yes		No	
	Frequency	Percent	Frequency	Percent
Diesel Generator	8	24.2	25	75.8
Electricity	33	100	0	0
Wind	0	0	33	100.0
Solar	1	3.0	32	97.0

Table 4.5: The main sources of energy in the buildings

Source: Research, (2012)

Plate 4.4: Interior and exterior views of the Standard Chartered Bank Building along Chiromo Rd.

Source: Symbion Architects (2011)

4.4. Indoor Environmental Quality

4.4.1.Thermal comfort

For the tropical climate, thermal comfort is critical in maintaining a favorable indoor environment for buildings by keeping hot air out of the building. Of the techniques under investigation, more than three quarters of the buildings positively used the thermal mass (thick walls) to keep off heat from the interiors (Table 4.6). Although the thick walls absorb much heat from direct solar radiation, the time lag for stone is good enough to keep it cool during the day for over eight working hours and dissipate it at night before morning.

A third of the buildings used the atrium to achieve thermal comfort. The atrium aids air movement within the building through stack effect by allowing in cooler air through the fenestrations (openings) at lower levels and discharging the hot air at the roof level through the atrium. The courtyard works almost the same way as the atrium. Twenty two percent of the buildings had used the courtyard to shield the interior habitable spaces from direct solar gain. Other than ventilation, the atrium or courtyard enhances lighting and indoor space usage. The two Waumini houses along Westlands Road have a well-defined courtyard. The courtyard provides a serene outdoor environment which is very conducive for lounging and recreational activities.

The office blocks for Eden Square Building along Chiromo Road are strategically oriented to shield the other blocks from direct solar radiation hence defining a well landscaped court. In addition the court has been well landscaped with fountains and water ponds which aid in cooling the incoming air through evaporative cooling. Six percent of the buildings used ceiling fans which are mostly switched on to aid in air movement in the hot afternoons. Ceiling fans are much better than air conditioning which is run on CFC rich refrigerants which harm the environment besides the health related risks for the occupants. In situations where air conditioning cannot be avoided, solar powered extractor fans are a more sustainable option to aid air movement. None of the buildings used down drought cooling to enhance thermal comfort.

Control Element	Yes		No	
	Frequency	Percent	Frequency	Percent
Thermal mass	26	79	7	21
Ceiling fans	2	6	31	94
Down drought cooling	0	0	33	100.
Evaporate cooling	1	3	32	97
Courtyard	7	21	26	79
Atrium	11	33	22	67

Table 4.6: Thermal comfort control elements used in the buildings

Source: Research, (2012)

Most buildings surveyed were naturally ventilated. Different buildings employed various passive ventilation strategies to achieve thermal comfort. Eighty eighth percent of the buildings were naturally ventilated. Twenty two percent of the buildings used of air-conditioning. This was employed in buildings within areas where cross ventilation was not possible due to lack of inadequate fenestrations (openings) or poor architectural design. Generally most buildings scored highly on the aspect of passive ventilation. However, the older buildings can be retrofitted to enhance cross ventilation by improving the size of fenestrations especially the windows.

4.4.2. Day lighting and Views

A good building should be designed to make maximum use of natural lighting and ventilation .This reduces energy demand by simultaneously reducing costs and energy consumption, at the same time cutting on GHG emissions. In addition, this enhances the working environment that increases employee productivity. Buildings with bigger windows not only improve the day lighting of working space but in addition provide nice views to the users. Poor views contribute to sight pollution (visual blight) which can have a negative effect on employee productivity. Ninety seven percent of the respondents were happy with the views from their work stations, while 91 % confirmed to be comfortable working during the day, even with lights-off due to good window sizes that allow sufficient day lighting.

4.4.3. Indoor Air Quality

Indoor pollution occurs from sources that release gases or particles into the air which cause air quality problems within a building. These may include; inadequate ventilation, uncontrolled high indoor temperatures and high humidity levels, dampness, pesticides, wood preservatives; aerosol sprays; cleansers and disinfectants; moth repellents and air fresheners; and also the use of manufactured timber rich in formaldehyde and chemical ridden paints. More than two thirds of the buildings used acrylic- based paints for the interior finish which are more preferable due to their low Volatile Organic Content (VOC) than the oil-based paints used in 13% of the buildings (Figure 4.5). Excessive use of Volatile Organic Compounds can have adverse health and environmental effects.

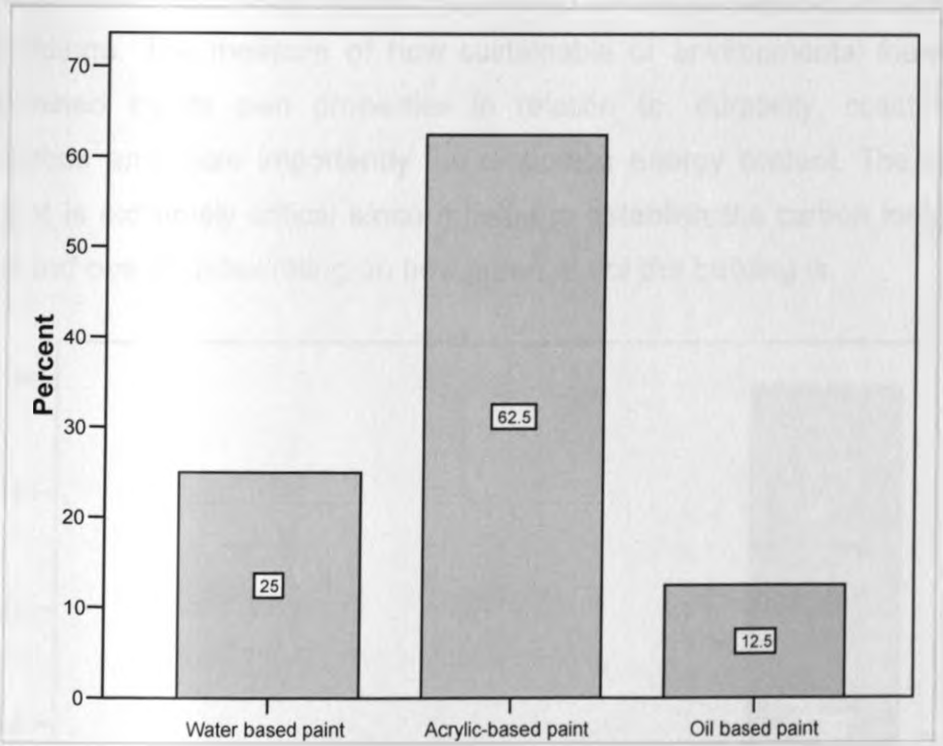


Figure 4.5: A graph showing the distribution of the type of paint used on the buildings studied

Source: Research, (2012)

Only 15 % of the buildings had smoking zones. Excessive use of detergents, aerosols and sprays can also be harmful to the environment since most detergents are non-biodegradable. However, most organic soaps are biodegradable and environmental friendly. 97% of the buildings used detergents, 12% used soaps and 3% used foams and sprays (Table 4.6). Overreliance on detergents for cleaning is a negative trend most property managers should aspire to reverse.

Cleaning agent	Yes		No	
	Frequency	Percent	Frequency	Percent
Foams and Detergents	2	6	31	94
Detergents	32	97	1	3
Soaps	4	12	29	88

Table 4.6: The type of cleaning agents use in the buildings

Source: Research, (2012)

4.5. Materials and Resources

The study also sought to investigate the overall contribution of building materials, physical resources, social capital, and human resources have on the overall performance of buildings. The measure of how sustainable or environmental friendly a material is determined by its own properties in relation to: durability, coast of maintenance, aesthetics and more importantly the embodied energy content. The embodied energy content is extremely critical since it helps to establish the carbon footprint of materials used and overall index/rating on how green or not the building is.

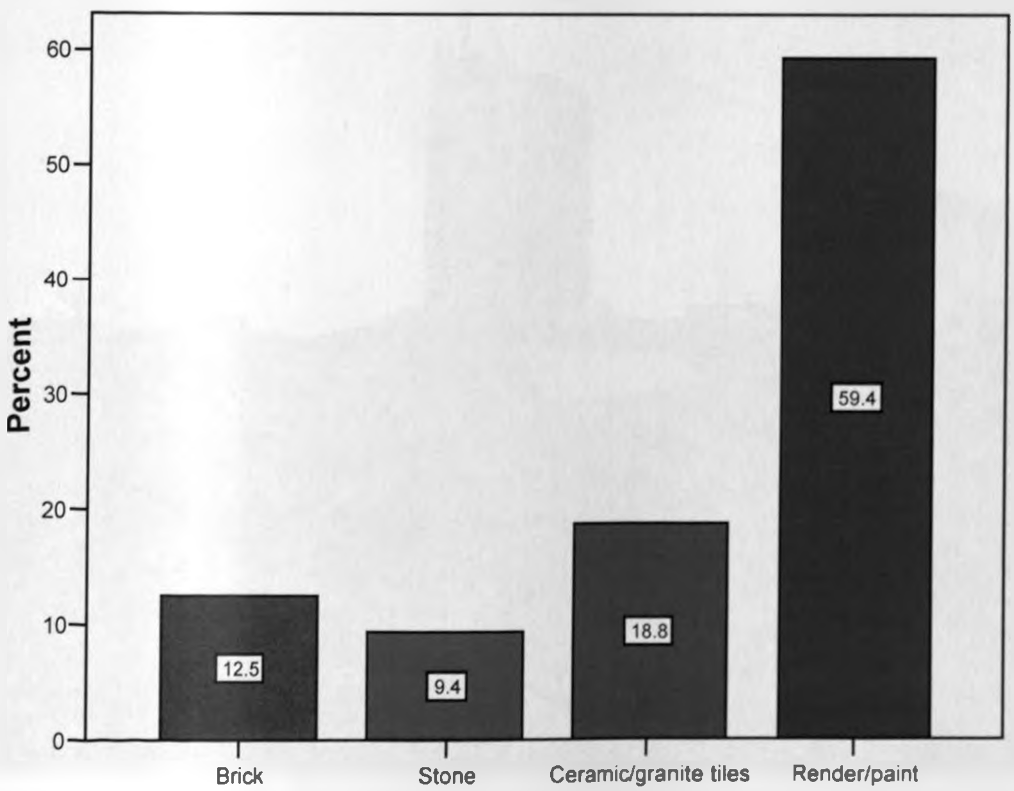


Figure 4.6: A graph showing the distribution of the type of external finishes used on the buildings studied

Source: Research, (2012)

Almost two thirds of the buildings under study had render and paint as their external finish (Figure 4.6). The preference of render as finish is pegged on its cost implication in the short term but it is expensive in the long term since the buildings will demand a fresh coat of paint on the minimum on an annual basis. The measure of how sustainable a paint as a finish is, is dependent on the base solvent used. Most oil based paints are laden with VOC which are harmful to human health and the environment.

Ceramic or granite tiles were preferred as an external finish by 19% of the buildings. Bandari Plaza along Woodvale Groove had ceramic tiles as an eternal finish. Compared to paint, these tiles are much better owing to their durability and maintenance properties. Nine percent of the buildings used stone as an external finish. Stone as a wall finish is durable and is a low maintenance finish. In addition, stone is mined and used almost within the same locality hence low embodied energy and consequently a low energy footprint. Brick as a finish was used on 13 percent of buildings. Brick has good qualities similar to stone especially if they are not fired bricks because emission of GHGs.

Plate 4.5: A view of brick cladded and well sun-shaded Brick Court building along Mpaka Road

Source: Research, (2012)

For internal wall finishes, the type of finishes used were largely dictated by the function of that particular space. Almost all the buildings used render and paint as the finish of choice for their interiors. Its negative impacts on the environmental and human health notwithstanding, its affordability and availability makes it an attractive alternative. More than two thirds of the buildings used acrylic based paint. Six percent of the buildings preferred to use ceramic/granite tiles to finish their interiors especially in the lobbies and wet areas.

Similarly to other interior finishes, the type of floor finish was dependent on the function intended. Twelve percent of the buildings used PVC to finish their floors. However, this type of finish was noted to have been used only in the older buildings. Terrazzo was also a popular floor finish with older buildings, 39% of the buildings had terrazzo floors. Granite tiles were used in 24% of the buildings while 3% had used timber flooring. Wooden floor was the least common floor type. Varied textured and pattern ceramic tiles and laminates were common alternatives to wood parquet. However, bamboo flooring is a more sustainable alternative to wooden flooring; unfortunately none of the buildings had used it.

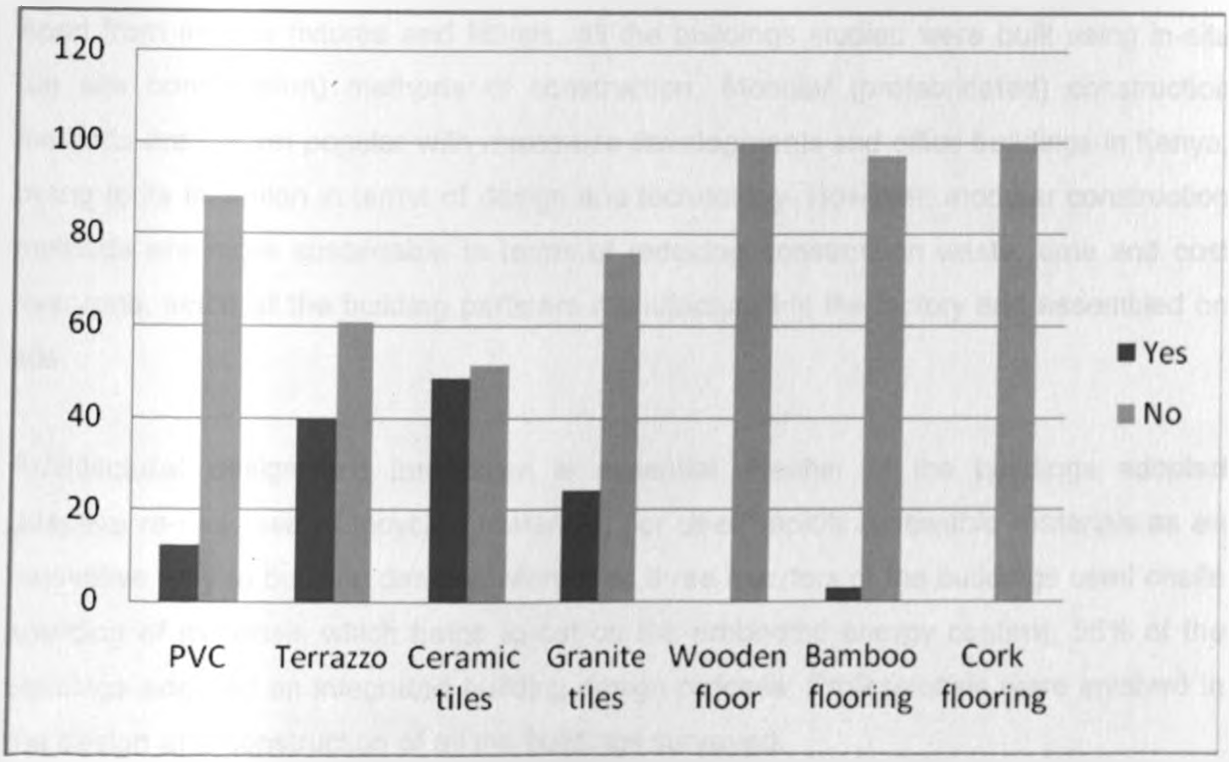


Figure 4.7: A graph showing the distribution of the type of floor finish used on the buildings studied

Source: Research, (2012)

Disposing of solid waste from the buildings was also one area the research looked at. All the buildings surveyed use dumping as their preferred choice to dispose–off solid waste. Unfortunately, municipal dumpsites are the biggest source of methane and nitrous oxide gases that cause global warming. Property managers should aspire to embrace sustainable waste management methods like recycling and re-use.

Table 4.8: Innovative Design and Construction procedures used on the buildings

	Yes		**No**	
	Frequency	Percent	Frequency	Percent
Adaptive building Re-use	0	0	33	100.0
Use of recycled materials	0	0	33	100.0
Use of rapidly renewable materials	2	6.1	31	93.9
On site sourcing of building materials	26	78.8	7	21.2
Integrated building design process	18	54.5	15	45.5
Architectural design innovation	11	33.3	22	66.7

Apart from interior fixtures and fittings, all the buildings studied were built using in-situ (on site construction) methods of construction. Modular (prefabricated) construction methods are not yet popular with mixed-use developments and office buildings in Kenya, owing to its limitation in terms of design and technology. However, modular construction methods are more sustainable in terms of reducing construction waste, time and cost over-runs, since all the building parts are manufactured in the factory and assembled on site.

Architectural design and innovation is essential. Neither of the buildings adopted adaptive re-use, use of recycled materials, nor used rapidly renewable materials as an innovative way to building design. More than three quarters of the buildings used onsite sourcing of materials which helps to cut on the embodied energy content. 55% of the buildings adopted an integrated building design process. Professionals were involved in the design and construction of all the buildings surveyed.

4.6. Results of Hypothesis Testing

After data analysis using the Statistical Package for Social Scientists (SPSS).The obtained results were used to give a rating to the buildings based on the weighted score of all the credits under the five categories matched-up against the maximum available points. The weighted score was classified into frequencies out of a total of 84 points, to give each building a rating as follows:

SCORE	RATING	NO. OF BUILDINGS
71-84	5 STAR	0
54-71	4 STAR	0
36-53	3 STAR	3
18-35	2 STAR	28
1-17	1 STAR	2

Table 4.9: A summary of green star rating of the buildings

Source: Research, 2012.

Form the research findings obtained above, out of the 33 buildings investigated under the study; 2 buildings got a "3 Star Green rating", 2 buildings a "1 Star Green rating", and the rest got a "2 Star Green rating". For the hypotheses testing; two buildings were selected from each rating category and the results cross tabulated for hypothesis testing. Since the quantitative data processed and analyzed was in the ordinal format, a non-parametric test was carried out using a Chi Square test. The chi-square (X^2) test was used to determine whether there is a significant difference between the expected frequencies of a green building weighted score and the observed frequencies in all the five categories under investigation as earlier hypothesized. From the research findings, it was established that;

1. There are no standards for the design of a green building in Nairobi
2. Buildings within the area of study do not qualify as green buildings
3. The designated green buildings within the area of study make no contribution to climate change mitigation

Table 4.10: A Rota for Green Buildings in Nairobi based on The Study Area

Source: Research, 2012.

	Sustainable Site Development	Water Efficiency	Energy Efficiency	Indoor Environ. Quality	Materials and Resources	Weighted Score	Green Rating
Eden Square	6	3.5	14.5	11	7	**42**	3 star
New Stanchart House	2.5	10	15	8.5	7	**43**	3star
Brick court	2	2.5	11	10	11.5	**37**	3 star
Soin Arcade	3	3.5	8.5	7.5	8.5	**31**	2 star
Purshotam Place	4	3	5.5	6	5	**23.5**	2 star
Niniva Towers	4	3.5	10.5	6.5	5.5	**30**	2 star
Westlands Arcade	3	0.5	6	6.5	5.5	**21.5**	2 star
Occidental Plaza	1	2.5	9	5.5	12.5	**30.5**	2 star
Fuji Plaza	3.5	2	10.5	5	7.5	**28.5**	2 star
Centro house	4	3	8	2	5.5	**22.5**	2 star
Tausi Assurance	3	3	6	5	5	**22**	2 star
West-end Building	3	3.5	8	5.5	9	**29**	2 star
Linwood House	1.5	1.5	13	5	7.5	**28.5**	2 star
The Citadel	3	4	4	5.5	8.5	**25**	2 star
Shimmers plaza	3	2.5	6.5	2.5	9.5	**24**	2 star
Vision Tower	4	3	2.5	5.5	6	**21**	2 star
Ojijo Plaza	3	3.5	4.5	6.5	8.5	**26**	2 star
Avocado Towers	4	3	6	4.5	6	**23.5**	2 star
Amee Arcade	4	3	9	7.5	5	**28.5**	2 star
Parklands plaza	2	3.5	5.5	7.5	5.5	**24**	2 star
Jimkan House	2	2.5	2.5	7.5	7	**21.5**	2 star
TVR Office Building	3	3	5.5	7.5	6.5	**25.5**	2 star
Design Centre	4	3	4	5	6	**22**	2 star
Woodvale Centre	3	0.5	7	4.5	7.5	**22.5**	2 star
Old Waumini House	3	0.5	5.5	7.5	6.5	**23**	2 star
Apic Centre	2.5	2.5	11	7	8	**31**	2 star
Lion Place	3.5	3.5	9.5	5	5	**26.5**	2 star
Unga House	2	3	6	5.5	4.5	**21**	2 star
Bandari Plaza	1.5	3.5	2.5	7	7	**21.5**	2 star
Sound Plaza	1.5	2.5	4.5	7.5	6.5	**22.5**	2 star
New Waumini House	3	0.5	5.5	7.5	5	**21.5**	2 star
Mpaka House	1.5	3	3	4.5	5	**17**	1 star
Fedha Plaza	2	0.5	4	4	4.5	**15**	1 star

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary

As earlier hypothesized, this study established that; First, most buildings in the area of study do not qualify as green buildings. Secondly, there are no standards for designing green buildings in Nairobi. Finally, the existing green buildings within the area of study make no significant contribution to climate change mitigation. Out of the 33 buildings investigated; 2 buildings got a 3 "Star Green Rating", 2 buildings got a 1"Star Green Rating", and the rest got a 2 "Star Green Rating" (Table 4.10). The greenest building had a weighted score of 43 points out of a total weighted building score of 84 points.

The category in which all the buildings performed dismally was on water efficiency. The average building score was 3.5 points out of the 12 available points. This is paltry 21% water efficiency rate. The building that had the highest score of 10 points under water efficiency was The New Standard Chartered Headquarters. This was attributed by their investment in waste water treatment equipment which recycles both the grey and black water on site for re-use. This building also scored highly in technological innovation to enhance water efficiency through the use of remote sensors instead of conventional taps, this enhances efficiency at the same time reducing the chances of leaving running taps when not in use, hence cutting on water costs.

On sustainable site development, the average score by the buildings surveyed was 3.0 points out of the available 14points. Almost three quarters of the buildings had flat roofs covered in asphalt shingles and felt which is a bituminous based finish; this is representative of the bigger picture of high rise office buildings in Nairobi. Asphalt has got high heat absorption capabilities, low heat emissivity and low reflectance levels consequently a higher heat island effect. Very few buildings had used reflective materials as a deliberate roof finish. In most instances; the 27% that used GCI sheets was an afterthought for solving the roof linkages prone to flat roofs.

Most buildings did not demonstrate a sustainable approach to outdoor space utilization. Other than planting of flowers, over 81% of the buildings surveyed had no single tree planted on site. The built-up area covered most of the building plot leaving very little open spaces other than the statutory building lines and setbacks which were left as building frontages or car parking covered with hard landscaping. Most buildings were properly oriented; the few that were wrongly oriented were sufficiently sun shaded to cut off direct solar gain. Eden Square Building along Chiromo had the highest score of 6 points. The central court defined by three building blocks with a well landscaped piazza with lawns, ponds, pools as well as a terrace for people to sit out creating a conductive and relaxed outdoor environment.

To mitigate climate change, most buildings in Nairobi should endeavour to score a higher rating on energy efficiency and alternative green energy sources, since this is the category where most GHGs are emitted in buildings through lighting, heating and ventilation. The energy efficiency score was slightly below average at 8 points out of the available 25 points. However some buildings had made a deliberate attempt to enhance energy efficiency. Out of the 33 buildings studied, 9 buildings managed a score of 10 points with the New Standard Chartered Building along Chiromo Road having a highest score of 15 points out of 25 available points. This was attributed to the adoption of green energy from solar for water heating and technological innovation by use of infrared sensors and switches throughout the building. Some buildings achieved energy efficiency through sufficient day lighting like The Brick Court Building along Mpaka Road.

Indoor air quality is a major consideration for a good indoor environment. The buildings with generous fenestrations, high day lighting levels, good views and passive interior spaces like atria and courtyard registered higher scores due to less visual and air pollution. Apic Centre along Mpaka Road is one such building. Use of detergents was one major concern discovered during the study. Ninety seven percent of the buildings surveyed use detergents, 12% use soap and 3% foams and sprays.

Material and resource use in the building is a primary concern for buildings in Nairobi. All buildings studied were built using in situ construction which is prone to material wastages and inefficiency, no modular construction methods ware used. The phasing out of PVC finishes in the newer buildings was a positive stride. It is also positive to note that all the buildings engaged professionals through an integrated building design process.

5.2. Conclusions

This research was guided by specific research questions and clear objectives. As earlier hypothesized, it can be concluded that;

1. Based on the key findings from the research, it was established that, There is no common definition of a green building in the context of climate change. **Therefore in the Kenyan context, a Green Building can be defined as that building that uses energy, water and other resources efficiently through passive design, protects occupant health and improve productivity, reduced waste production and has minimal environmental degradation.**
2. Majority of buildings in the area of study do not qualify as Green Buildings, hence there are no common design standards for green buildings in the area of study
3. There is no inventory of best practice(s) in Green Buildings in the area of study due to lack of a standard system to asses performance of buildings in Kenya.
4. Due to the dismal scores in the key performance areas of energy and water efficiency, most buildings in the area of study have an insignificant contribution to Climate Change Mitigation.

5.3. Recommendations

Based on the key findings obtained from this research, this study makes the following recommendations;

1. The government together with the private sector should formulate a legal and policy framework in the laws of Kenya to guide and promote green architecture.
2. As a member of the World Green Building Council, Kenya should set up The Kenya Green Building Council to spearhead the green building agenda in Kenya. The council will also establish a "Green Star Kenya" rating system and green building awards for best practice in green architecture to promote and encourage innovation and sustainable construction.
3. With rapid urbanization, local authorities should promote sustainable urban planning in line with the global best practice(s).

REFERENCES

Allen, Edward, Iano, J. (2003). *Fundamentals of Building Construction: Materials and Methods*, Fourth Edition, John Wiley, New York.

Anyamba, T. (2008), *Diverse Informalities" Spatial Transformations in Nairobi: A study of Nairobi's urban process*. Andreas Papadakis Publisher, London.

ASHRAE (2008), Proposed Standard 189P: *Standard for the Design of High-Performance Green Buildings, Second public review*, Atlanta.

Bauer, Mosle, Schwarz, M. (2007), *Green Building: Guidebook for Sustainable Architecture*, Callwey Verlag, Munich.

Berdahl and Bretz, S. (1997), *Preliminary survey of the solar reflectance of cool roofing materials, Energy and Buildings.*

City Council of Nairobi (2004), *A Guide of Nairobi City Development Ordinances & Zones*, Unpublished Report: Department of City Planning, City Council of Nairobi

Deasy, M. (1985). *Designing Places for People: A Handbook for Architects, Designers, and Facility Managers*, Whitney Library of Design, New York.

Edwards and Sandra, (1986). Office Systems: *Designs for the Contemporary Workspace*, PBC International Inc., New York.

Fowler and Rauc, M. (2006), *Sustainable Building Rating Systems Summary.*

Gibberd, Jeremy, et al. (2005), *Assessing Sustainable Buildings in Developing Countries: The Sustainable Building Assessment Tool (SBAT) and the Sustainable Building Life Cycle:* Tokyo, Japan

Government of Kenya (1992), The National Water Master Plan, Government Printers

Government of Kenya (1970); *The Public Health Act,* Government Printers: Nairobi.

Government of Kenya (1969); *Building code: The local government (Adoptive by-laws) (building) order 1968*. Government Printers: Nairobi.

International Energy Agency. (2007), *Energy Efficiency of Air Conditioners in Developing Countries and the Role of CDM.*

IPCC (2000), *Emissions Scenarios, IPCC Special Report*. Cambridge University Press: Cambridge.

IPCC (2001), *Climate Change 2001: Impacts, Adaptation and Vulnerability*. Cambridge: Cambridge University Press.

IPCC (2007), IPCC 4th Assessment Report. *Working Group III Report "Mitigation of Climate Change"*. Chapter 6. Residential and Commercial Buildings.

Jaygopals, P. (2008), *Architecture and Development, Energy efficiency and high environmental quality buildings in India*

Kenya National Bureau of Statistics (2009), *Kenya Population and Housing Census Report*, Nairobi.

Kubba, S. (2010), *LEED Practices Certification and Accreditation Handbook*, McGraw-Hill Companies Inc., New York.

Lee and Burnett, J. (2008), *Benchmarking energy use assessment of HK-BEAM, BREEAM and LEED, Building and Environment.*

Mitchell, L. (2009), Green Star and NABERS: Learning from the Australian experience with green building rating tools.

Macaluso, J. (2009), *An Overview of The LEED Rating System,* Empire State Development, Green Construction Data.

McGraw, H. (2008), *Emerald Architecture case studies in Green Building*, Green Source Magazine, McGraw-Hill Companies Inc., New York.

McDonough, W. and Gissen D. (2002). *Big and Green: Toward Sustainable Architecture in the 21st Century*. New York: Princeton Architectural Press.

Mitullah, Winnie, (2003).*Understanding Slums: Case Studies for the Global Report on Human Settlements 2003: The Case of Nairobi, Kenya*. UN-HABITAT Nairobi.

O'Brian, Mary and Nile J. (2003), *Building better buildings: The Transition to Environmental Building in Canada*, University of Waterloo, Canada.

Rakodi, C. (1997), *Urban Challenge in Africa: Growth and Management of Its Large Cities*. United Nations University Press, Tokyo.

Saggerson, E. (1991), *Geology of the Nairobi Area. Degree Sheet 51. Mines and Geology Department*. English Press, Nairobi, Kenya.

Syagga, Mitullah, and Gitau S. (2002), *Nairobi Situation Analysis. Supplementary Study: A Rapid Economic Appraisal of Rents in Slums and Informal Settlements*, Government of Kenya and UN-Habitat, Nairobi.

UNFPA (2001), *Population and Sustainable Development*. United Nations Population Fund.

UN-HABITAT (2003), *The Challenge of Slums: Global Report on Human Settlements.* Nairobi, Kenya

UNEP (2007), *Buildings and Climate Change: Status Challenges and Opportunities.* Nairobi, Kenya

UNEP (2007), *Common Carbon Metric Protocol for Measuring Energy Use and Reporting Greenhouse Gas Emissions from Building Operations*. Nairobi, Kenya

UNEP (2008), *Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World,* UNEP/ILO/IOE/ITUC. Nairobi, Kenya

UNEP (2009), *A Case for Climate Neutrality: Case Studies on Moving Towards a Low Carbon Economy*. Nairobi, Kenya

UNEP (2011), *Building for the future: A United Nations showcase in Nairobi*, Nairobi, Kenya

Weil S. et. al. (1998), *The role of building energy efficiency in managing atmospheric carbon dioxide*. Environmental Science & Policy. Volume 1, Issue 1,

Woods, E. (2008), *Expanding the principles of performance to sustainable buildings, Focus on Green Building*, Entrepreneur Media, Inc.

Yeang, K. (1995), *Designing with Nature: the ecological basis for architectural design*, McGraw Hill, New York.

Yoders,J.,(2008).*"Integrated Project Delivery Using BIM," Building Design and Construction.*

APPENDICES

Appendix I Work Plan

DATE/TIME	ACTIVITY
AUGUST 2011	Project Proposal • Identification of Study Area • Approvals and research permits • Finalization of Project proposal
SEPTEMBER 2011	Data Collection • Sampling • Data collection instruments • Data collection procedures
SEPTEMBER 2012	Data Processing and analysis • Processing Procedure • Methods of Data Analysis • Data Presentation • Project Presentation

Appendix II Budget

Stationery	7,000
Travel expenses	7,000
Data collection	12,000
Data Analysis	15,000
Miscellaneous	9,000
TOTAL EXPENSES	**50,000**

Appendix III Questionnaire

QUESTIONNAIRE FOR PROPERTY AGENTS / PROPERTY MANAGERS OF THE SELECTED OFFICE BUILDINGS IN WESTLANDS, NAIROBI

Dear Sir/Madam,

I am a Master of Environmental Planning and Management student at the University of Nairobi undertaking a study on the "The Impact of Green Buildings in Climate Change Mitigation: An Investigative Study of Office Buildings in Westlands, Nairobi". This exercise is part of the project towards fulfilling the requirements of the course. I would be obliged if you could provide me with some of your valuable time to answer the following questions.

Name of Building...No. of Stories ....

Street/Road..................................... Property Agent ....

Based on your experience as a Property Agent/property manager of this building, kindly assist me to complete the questionnaire below. Tick **[ ]**, the box for the appropriate answer for each question

1.0. SUSTAINABLE SITE DEVELOPMENT

1.1. Site Selection and Development

1. Is your building on a reclaimed wasteland?

   ☐ Yes

   ☐ No

2. How is your building oriented?

   ☐ East –West

   ☐ North –South

3. Do you harvest storm water on-site for reuse?

   ☐ Yes

   ☐ No

1.2. Heat Island Effect

4. Have you planted trees on-site?

   ☐ Yes

   ☐ No

5. What material have you used for pathways and driveways?

- ☐ Asphalt
- ☐ Concrete blocks
- ☐ Gravel
- ☐ Grass

6. What type of roof does your building have?

- ☐ Galvanized Corrugated Iron (GCI) Sheets
- ☐ Tiles
- ☐ Asphalt shingles/felt
- ☐ Green (planted)roofs

2.0. WATER EFFICIENCY

2.1. Water Efficient Landscaping

7. Have you used native plants for landscaping?

- ☐ Yes
- ☐ No

8. Do you irrigate your plants?

- ☐ Yes
- ☐ No

If yes where is the source of your water?

- ☐ NW&SC
- ☐ Borehole Water
- ☐ Stormwater/Rainwater
- ☐ Recycled water

2.2. Innovative Wastewater Technologies

9. Do you recycle grey (sink and bathroom) water on site?

- ☐ Yes
- ☐ No

10. Do you recycle black (sewer) water on site?

- ☐ Yes
- ☐ No

2.3. Water Use Reduction

11. What is the main source of water used in your building?

- ☐ NW&SC
- ☐ Borehole water
- ☐ Rainwater
- ☐ Recycled water

If NW&SC, state the average consumption of water per month in both litres and KShs

- ☐ Litres--------------------------
- ☐ KShs---------------------------

12. What water-use reduction technologies do you use in your building?

- ☐ Push taps
- ☐ Dual-flush toilets
- ☐ Waterless urinals
- ☐ Infrared-flush sensors

3.0. ENERGY EFFICIENCY

3.1. Energy Conservation

13. Is your building sun shaded?

- ☐ Yes
- ☐ No

If yes, what sun shading devices are used?

- ☐ Reflective glass
- ☐ Heat absorbing glass
- ☐ Double glazing
- ☐ Generous overhangs
- ☐ Concrete aluminum fins
- ☐ Recessed windows
- ☐ Large eaves and roof overhangs

14. What type of lighting fixtures do you use in your building?

- ☐ Incandescent Bulbs
- ☐ Fluorescent Tubes
- ☐ Compact fluorescent tubes
- ☐ LED lights

15. What type of lighting switches do you use?

- ☐ Wall switches
- ☐ Light Dependent Resistor (LDR) switches
- ☐ Infra-red Sensors

3.2. Green power

16. What is the main source of energy in your building?

- ☐ Diesel Generator
- ☐ Electricity
- ☐ Wind
- ☐ Solar

If electricity, state the average consumption of electricity per month in KWh and KShs

- ☐ KWh-----------------------------
- ☐ KShs---

4.0. INDOOR ENVIRONMENTAL QUALITY

4.1. Thermal comfort

17. What thermal comfort control element does your building use?

- ☐ Thermal mass (Thick walls)
- ☐ Ceiling fans
- ☐ Down drought cooling
- ☐ Evaporative cooling
- ☐ Courtyard
- ☐ Atrium

18. How is your building ventilated?

- ☐ Air conditioning
- ☐ Natural ventilation

4.2. Day lighting and Views

19. Are you able to work during the day with your lights off?

- ☐ Yes
- ☐ No

20. How can you describe the views and vistas though your windows?

- ☐ Good
- ☐ Bad

4.3. Indoor Air Quality

21. Do you have smoking zones in your building?

- ☐ Yes
- ☐ No

22. What type of paint have you used for interior finishes in your building?

- ☐ Oil-based paint
- ☐ Acrylic-based paint
- ☐ Water based paint

5.0. MATERIALS AND RESOURCES

23. What materials are the walls of your building made of?

- ☐ Stone
- ☐ Concrete
- ☐ Steel
- ☐ Aluminum

24. What material are the roofs of your building made of?

- ☐ Asphalt
- ☐ Wood shingles
- ☐ Steel

25. What material are the floors of your building made of?

- ☐ PVC
- ☐ Ceramic/Granite/Granito tiles
- ☐ Timber
- ☐ Concrete
- ☐ Cork

26. How do you dispose-off solid wastes from your building?

- ☐ Incinerate (burn)
- ☐ Dumping
- ☐ Recycle

27. What method of construction was used for your building?

- ☐ In-situ construction
- ☐ Modular construction

28. What cleaning agents do you use?

- ☐ Sprays Soaps
- ☐ Foams
- ☐ Detergents
- ☐ Soaps

29. Which of the following innovative design and construction procedures were used on your building?

- ☐ Use of recycled materials
- ☐ Advanced technological innovation
- ☐ On-site sourcing of building materials
- ☐ Integrated building design process

30. Were professionals involved in the design and construction of your building?

- ☐ Yes
- ☐ No

Appendix IV Data Entry Score Sheet

ITEM NO.	SUSTAINABLE DESIGN ELEMENT	AWARDED POINTS	MAXIMUM POINTS	TOTAL SCORE	ENVIRONMENTAL COMPONRNT
1.0	SUSTAINABLE SITE DEVELOPMENT			14.0	
1.1	**Site Selection and Development**				Surface run-off
1.1.1	Is your building on a reclaimed/wasteland?				Permeable paved surfaces
	▪ Yes		1.0		
	▪ No		0.0		
1.1.2	How is your building oriented?				
	▪ East –West		0.0		
	▪ North –South		1.0		
1.1.3	Do you harvest storm water on-site for reuse?				
	▪ Yes		1.0		
	▪ No		0.0		
1.2	**Heat Island Effect**				Solar reflectance (albedo),
1.2.1	Have you planted trees on-site?				Emittance
	▪ Yes		1.0		Solar Reflective Index
	▪ No		0.0		Heat absorption
1.2.2	What material have you used for pathways and driveways?				
	▪ Asphalt		0.5		
	▪ Gravel		1.0		
	▪ Concrete blocks		1.5		
	▪ Grass		2.0		
1.2.3	What type of roof does your building have?				
	▪ Asphalt shingles/felt		0.5		
	▪ Roof Tiles		1.0		
	▪ Galvanized Corrugated Iron (GCI) Sheets		1.5		
	▪ Green (planted)roofs		2.0		
2.0	WATER EFFICIENCY			14.0	
2.1	**Water Efficient Landscaping**				
2.1.1	Have you used native plants for landscaping?				
	▪ Yes		1.0		
	▪ No		0.0		
2.1.2	Do you irrigate your plants?				Xeriscape landscaping
	▪ Yes		1.0		
	▪ No		0.0		

2.2	**Innovative Wastewater Technologies**				On-site wastewater treatment
2.2.1	Do you recycle grey (sink and bathroom) water on site?				
	• Yes		1.0		
	• No		0.0		Sustainable water use(Water recycling. reused)
2.2.2	Do you recycle black (sewer) water on site?				
	• Yes		1.0		
	• No		0.0		
2.3	**Water Use Reduction**				
2.3.1	What is the main source of water used in your building?				
	• NW&SC		0.5		
	• Borehole water		1.0		
	• Rainwater		1.5		Sustainable water sources
	• Recycled water		2.0		
2.3.2	What water-use reduction technologies do you use in your building?				
	• Push taps		0.5		Water efficiency
	• Dual-flush toilets		1.0		Water conservation
	• Waterless urinals		1.5		
	• Infrared-flush sensors		2.0		
3.0	**ENERGY EFFICIENCY**			**25.0**	
3.1	**Energy Conservation**				
3.1.1	What type of lighting fixtures do you use in your building?				Energy conservation
	• Incandescent Bulbs		0.5		Energy efficiency
	• Fluorescent Tubes		1.0		Long life lighting fixtures
	• Compact fluorescent tubes		1.5		
	• Light Emitting Diodes (LED) lights		2.0		
3.1.2	What type of lighting switches do you use?				
	• Wall switches		0.5		
	• Light Dependent Resistors (LDR) switches		1.0		
	• Infra-red Sensors		1.5		
3.1.3	Is your building sun shaded?				
	• Yes		1.0		
	• No		0.0		
	If yes, what sun shading devices are used?				Heat Island Reduction
	• Reflective glass		0.5		
	• Heat absorbing glass		1.0		Indoor temperature control
	• Double glazing		1.5		

	• Concrete /aluminum fins		2.0		Direct heat gain
	• Recessed windows		2.5		
	• Large eaves and roof overhangs		3.0		
3.2	**Green power**				
3.2.1	What is the main source of energy in your building?				Sustainable energy
	• Diesel Generator		0.0		Air pollution
	• Electricity		1.0		Greenhouse gases emission
	• Wind		2.0		
	• Solar		2.5		
4.0	**INDOOR ENVIRONMENTAL QUALITY**			**12.0**	
4.1	**Thermal comfort**				
4.1.1	What thermal comfort control element does your building use?				Indoor thermal comfort/room temperature control
	• Ceiling fans		0.5		
	• Thermal mass (Thick walls)		0.5		
	• Down drought cooling		1.0		
	• Evaporative cooling		1.0		
	• Courtyard		1.5		
	• Atrium		2.0		
4.1.2	How is your building ventilated?				Air movement/breezes
	• Air conditioning		0.0		
	• Natural (Cross) ventilation		1.0		Use of CFCs/HCFCs, foams
4.2	**Day lighting and Views**				
4.2.1	Are you able to work during the day with your lights off?				Good day lighting
	• Yes		1.0		
	• No		0.0		
4.2.2	How can you describe the views and vistas though your windows?				Sight pollution
	• Good		1.0		
	• Bad		0.0		
4.3	**Indoor Air Quality**				
4.3.1	Do you have smoking zones/detectors in your building?				Good Air quality/air pollution
	• Yes		1.0		
	• No		0.0		
4.3.2	What type of paint is used for interior finishes in your building?				
	• Oil-based paint		0.0		
	• Acrylic-based paint		0.5		
	• Water based paint		1.0		Low VOC materials

5.0	MATERIALS AND RESOURCES			19.0	
5.1	What materials are used for external wall finishes?				
	• Render/paint		0.5		Maintenance-free finishes
	• Ceramic tiles		1.0		
	• Concrete		1.5		
	• Stone/brick		2.0		
5.2	What materials are used for internal wall finishes?				
	• Render /paint		0.5		Low embodied energy materials
	• Ceramic tiles		1.0		
	• Stone/brick		1.5		
5.3	What materials are used for the floor finishes?				
	• PVC		0.0		Durable and low-maintenance finishes
	• Ceramic/granito tiles		0.5		
	• Wooden floor		0.5		
	• Terrazzo		1.0		
	• Granite		1.0		
	• Bamboo flooring		1.5		
5.4	How do you dispose of solid wastes from your building?				
	• Incinerate (burn)		0.0		Sustainable waste management (3Rs)
	• Dumping		0.0		
	• Recycle		1.0		
5.5	What method of construction was used for your building?				Construction waste reduction
	• In-situ construction		0.0		
	• Modular construction		1.0		
5.6	What cleaning agents do you use?				
	• Foams and Sprays		0.0		Biodegradable cleaning agents
	• Detergents		0.0		Use of aerosols, foams, ozone depletion materials
	• Soaps		0.5		
5.7	Which of the following innovative design and construction procedures were used on your building?				
	• Adaptive building Re-use		0.5		Architectural design and innovation
	• Use of recycled construction materials		0.5		
	• Use of rapidly renewable materials		0.5		
	• On-site sourcing of building materials		0.5		
	• Integrated building design process		1.0		
	• Architectural design innovation		1.0		

5.8	Were professionals involved in the design and construction of your building?				
	• Yes		1.0		
	• No		0.0		Integrated building design process
	TOTAL SCORE			**84 POINTS**	

RATING SYSTEM

SCORE	RATING
71-84	5 STAR
54-71	4 STAR
36-53	3 STAR
18-35	2 STAR
1-17	1 STAR