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Project.

The Green Building Option; Environmentally Sustainable Building In Residential Building Designs, A Case Study Of Makongeni Area, Thika Town, Kiambu County.

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N36S/16470/2009

Declaration

This project proposal is my original work and has not been presented for a degree in any University nor educational institution.

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SIGNATURE: …………………………………..   DATE: ………………………

We confirm that the work presented by this student and his project proposal was carried out under our strict supervision.

DR. P.K KAMAU

Department of Environmental Planning and Management

SIGNATURE: …………………………………..   DATE: ………………………

Dedication

To my family and friend Beth, you will forever remain the motivation behind my hard work and for your support, encouragement and unconditional love.

Acknowledgement

I am grateful to my supervisor, Dr. P.K.Kamau for his guidance and counsel during the undertaking of this project. Mr. Kirui for his awesome coordination. To my classmates for their moral support and encouragement during this academic journey. I am grateful to the administration of Thika Sub County and the residentsof Makongeni for their time and information and Kenyatta University fraternity for the opportunity to complete my studies.

My earnest gratitude to my Family and friends whose effort and assistance made this study possible, I remain grateful and may God bless you greatly.

I will forever remain grateful and thankful to God for the care, wisdom and protection during the entire research and study process. Glory be to God.

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LIST OF ABBREVITIONS AND ACRONYMS

LEED- Leadership in Energy and Environmental Design

HVAC- Heating, Ventilation and Air Conditioning (HVAC)

VOC- Volatile Organic Compound

World GBC- World Green Building Council

SPSS- Statistical Package for Social Sciences

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1.1 Background

The issue about sustainable (green) building is becoming increasingly relevant globally, especially in the real estate sector. A 2013 McGraw-Hill Construction global report found that 51% of architects, engineers, contractors and consultants and building owners' surveyed in over 62 countries say it is likely more than 60% of their work will be "green" by 2015 (Initiative for Global Environmental Leadership, 2013).

Urban areas today hold more than half of the human population. They consume three quarters of global energy and responsible for 80% of carbon emission, according to a Schneider Electric white paper, "The Smart City Cornerstone: Urban Efficiency". The building sector has a major impact on the built and natural environment in that building activities i.e. design, construction and demolition phase directly or indirectly affect environmental performance of the sector.

Sustainable buildings are designed to reduce energy, materials, and resources on a life-cycle basis. Leadership in Energy and Environmental Design (LEED) identifies the categories of focus for green buildings to be Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, and Indoor Environmental Quality (Urban Redevelopment Authority, 2012).

The need to design buildings that enhance the environment instead of exploiting it becomes a reality. Driven by the increasing concerns about energy, greenhouse gas emissions and indoor air quality, an explosion in the interest of sustainable building is unmistakable (McGraw Hill Construction, 2008). Sustainable buildings reduce consumption of materials, energy, water, and improve indoor environmental health. The need to reduce the environmental footprint of buildings alongside the economic incentives to build green, presents a substantial opportunity for the real estate and construction sectors.

According to (US EPA, OAR, Climate Protection Partnerships Division, 2005), Principles of Green Building and Sustainable Site Design include;

- Evaluate site in terms of the location and orientation of buildings and improvements in order to optimize the use of passive solar energy, natural day lighting, and natural breezes and ventilation.
- Help reduce the urban heat island effect by maximizing the use of pervious surfaces, and using light colored roofs, paving, and walkways.
- Provide natural shading of buildings and paved areas with trees and other landscape features.
- Optimize the use of on-site storm water treatment and ground water recharge.
- Use landscape design to preserve and restore the region's natural habitat and heritage by using indigenous, hardy, drought resistant trees, shrubs, plants and turf.
- Help reduce night-time light pollution by avoiding over-illumination of the site and use low cut-off exterior lighting fixtures which direct light downward, not upward and outward.
- Designing and locating buildings to optimize use of storm water technologies such as bio-retention, rain gardens, open grassy swales underground water storage tanks and pervious bituminous paving.
- Minimize the building's footprint to absorb and store up to 80% of natural rainfall until it can be absorbed by vegetation or enter the site's natural sub-surface ground water system.
- Use energy efficient T-8 and T-5 bulbs, high efficiency electronic ballasts, and lighting controls. Incorporate sensors and controls and design circuits so that lighting along

perimeter zones and offices can be switched off independently from other interior lights when day lighting is sufficient in perimeter areas.

- Use state-of-the art, high efficiency, heating, ventilation and air conditioning (HVAC) and plumbing equipment, chillers, boilers, and water heaters.
- Optimize the use of natural ventilation and where practical use evaporative cooling, waste heat and/or solar regenerated desiccant dehumidification or absorption cooling.
- Identify ways to reduce the amount of materials used and reduce the amount of waste generated through the implementation of a construction waste reduction plan.
- Identify ways to use high-recycled content materials in the building structure and finishes.
- Use of bio-based materials and finishes such as various types of agri-board (sheathing and or insulation board made from agricultural waste and byproducts, including straw, wheat, barley, soy, sunflower shells, peanut shells, and other materials).

1.2 Problem Statement

Kenya has a large housing deficit which is growing every year and is increasingly prevalent in urban areas including Thika. According to the Ministry of Housing, the current annual housing deficit is estimated at 156,000 units per annum based on the population growth and urban migration currently taking place. The pace of construction is limited with only 50,000 units constructed and the deficit filled by growth in slum dwelling and poor quality traditional housing (Walley, 2011).

Makongeni serves as an economic and residential hub of Thika town. Makongeni was conceived in 1970 with the intention of providing sufficient plots to accommodate around 60 per cent of the predicted population growth in Thika.The rate of construction of buildings in Makongeni is high to accommodate the rising number of people looking for settlements. The major concern is that almost none of the building adopts the green sustainable design or technologies available in the market during their construction or occupational phases. Thus there will be an increase in the consumption and demand of building materials, energy, water, and improve indoor environmental health which in the long run will not be sustainable. This research seeks to assess the level of sustainable building designs and explores technologies that can be incorporated into building design to make them sustainable.

1.3 Justification

In the last 15 years, green development has evolved significantly especially in the developed countries. Sustainable building materials and products such as low VOC paints and adhesives, energy efficient lighting and other renovation materials are standard construction material in green building construction (University of Michigan, 2005). Research on the incorporation of green building design in Kenya is not intensively carried out at the moment nor have investors discovered the potential of green building construction. The benefits for this study have been grouped into three categories financial, environmental and social benefits. Financial benefits include reduced capital costs of construction, lower operating and maintenance cost during occupational phase of the housing project and reduced risks and liabilities. The environmental benefits will include reduced impact on the natural environment resources, healthier working and living space improvement for occupant productivity and environmentally responsible development increases overall environmental awareness. The current construction activities in Makongeni have not incorporated any of the above mentioned green building designs or technologies. The only initiative commonly used is use of solar energy for water heating. Given that the area of study has a great potential in real estate development, awareness for the need of green building strategies is a viable option in the construction phase.

1.4 Research Objectives

The overall objective of this study is to establish the level of sustainable buildings in Makongeni, and come up with strategies or green technologies that can be incorporated into building designs to reduce their ecological footprints.

1.5 Research Questions

1. What kinds of building design and materials are currently being used in Makongeni?
2. How has sustainable building design incorporated during construction phase in Makongeni?
3. What are the challenges faced in implementing sustainable green technology in Makongeni?
4. What type of sustainable building design can be used in Makongeni?
5. What measures can be employed to promote use of sustainable building design in Makongeni?

1.6 Null Hypothesis

There are no green building technologies/design that can be used in construction of residential or commercial building in Makongeni.

1.7 General objective

To investigate the type of environmentally sustainable (green) building options in Makongeni.

1.7.1 Specific Objectives

To establish the type of building design and materials used in Makongeni.

To determine sustainable building technologies currently in use in Makongeni.

To determine challenges faced in implementing green building technologies in Makongeni.

To establish types of sustainable building design that can be used in Makongeni.

1.8 Significance of the Study

This study will document environmentally sustainable building designs and technologies which could be made available to the real estate developers for use during construction of residential and commercial buildings. This will contribute towards a greener urban environment and also the Leadership in Energy and Environmental Design (LEED) agenda of promoting green building designs in urban areas (Initiative for Global Environmental Leadership, 2013). This study sheds light on the need to enhance high environmental quality standards by efficient utilization of natural resources and minimal disruption of both the built and natural environment as we strive towards a sustainable development and the vision 2030 pillars.

1.9 Scope of the study

This study examines the need of incorporating green or sustainable building technologies and design in the construction of commercial and residential buildings. Although Makongeni is divided into several phases, it will mainly focus on Makongeni Area phase 4 due to its expansion potential (currently undeveloped).

This study will assess how sustainable building design has been used in Makongeni. The effort to incorporate green building technologies during the construction, occupation and decommissioning phases of a building will also be discussed. The study will make recommendations on available sustainable building design and technologies that can be used to redefine Makongeni as an environmentally friendly neighborhood.

1.10 Conceptual Framework

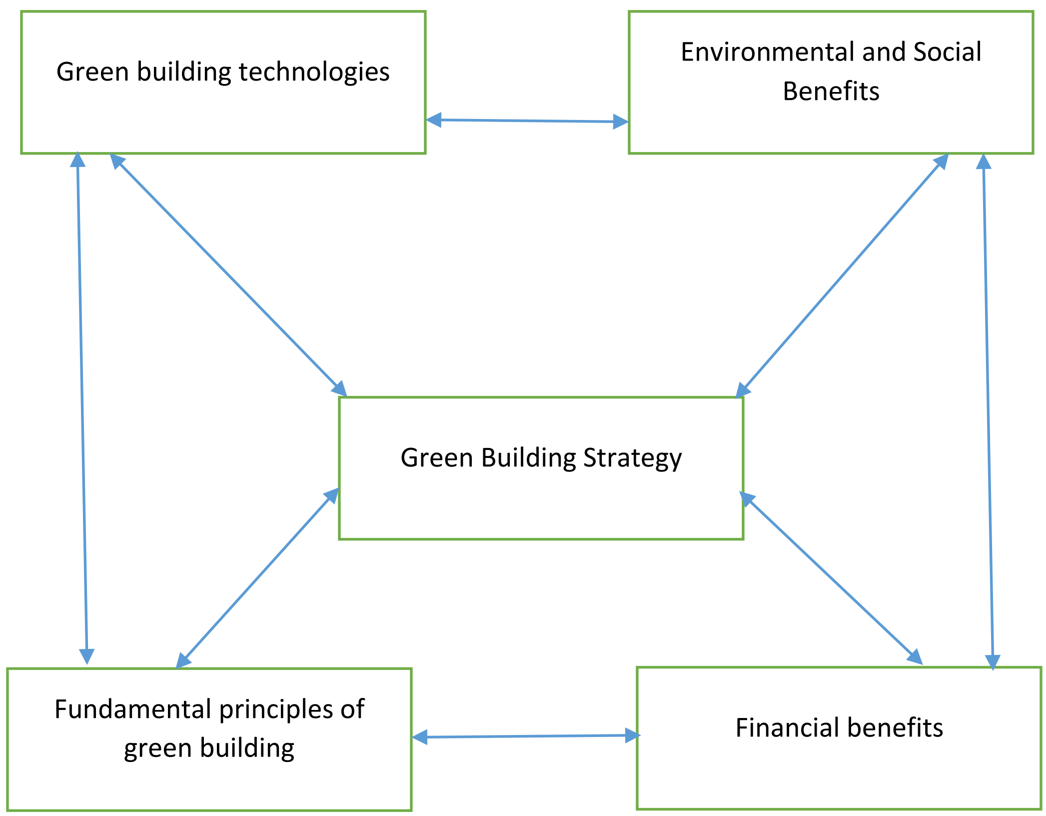

Figure 1: Conceptual Framework

Green building strategy: this include various building and design initiatives or strategy that are used during construction and occupational phases of a green building.

Green building technologies: this include the various construction material and products used in designing a green building.

Environmental and social benefits: this include gains that can be derived from green buildings in terms of environmental quality and human welfare.

Financial benefits: this include reduced capital costs of construction, lower operating and maintenance cost during occupational phase of the housing project.

Fundamental principles of green building: this include sustainable site design, water efficiency, energy efficiency, materials and resources and environmental quality.

2 CHAPTER TWO: LITERATURE REVIEW

2.1 Defining "Green Concept" in Building Design

Earlier research has addressed the incorporation of green building technologies into residential and commercial constructions from multiple point of views. Several authors have examined the financial, social and environmental benefits, in terms of the effects of green design and energy efficiency of "green concept". Some authors have addressed the cost factors including the decision to adopt energy efficient design as well as the overall cost of building green. Most research has been done by independent institution and organizations specialized in the field of construction and real estate sector.

Many definition of what a green building is or does exist. The ideal "green" project preserves and restores habitat that is vital for sustaining life and becomes a net producer and exporter of resources, materials, energy and water rather than being a net consumer. A green building is one whose construction and lifetime of operation assure the healthiest possible environment while representing the most efficient and least disruptive use of land, water, energy and resources (Governors Green Government Council , 2013). Advances in techniques and materials have made it possible to do what was unthinkable only a few years ago; Design buildings that enhance the environment instead of exploiting it (WaterFurnace International, 2011).An integrated design approach that addresses the potential of the site, water conservation, energy efficiency and renewable energy as well as selection of building materials and indoor environmental quality is used to define a green building.

In 2008, McGraw-Hill Construction (MHC) surveyed firm around the world to gain an insight into global green building trends. The study, "The Global Green building Trends SmartMarket

Report, was one of the first ever studies focusing on green building and aiming to discern differences driving the green building marketplace (McGraw-Hill Construction, 2013). Only 17 countries had official or emerging green building councils (GBCs) regrettably Kenya was not one of the countries. The World Green Building Council (World GBC) was growing to help the emerging GBC movement the emerging GBCs to share their experiences with other organizations. By 2012, global construction and economic situation was drastically different. After four years of construction activity declines and a global recession, construction activity had shifted to developing countries while developed countries battled with economic challenges. Development of GBCs grew gradually with GBCs in over 90 countries by 2012 including South Africa.

Sustainability is not just about green building design and construction. Cities around the world are in the early stages of mobilizing against the effects of global warming through green infrastructure solutions. Whether a ton of greenhouse gas emission is released in North America, Africa or Asia, its effect on the planet is the same. Reducing those emissions might be achieved a lot more economically with water purification project in Africa than with a roof full of Photovoltaic panels in the United States. That’s the principle behind global carbon markets.

International real estate markets are diverse, embracing green building in different ways and at different levels. According to U.S Government data, building account for 60% of the raw materials used in the United States and 40% of non-industrial solid waste, 65% of electricity consumption, 48% of greenhouse gas emissions and 12% of portable water consumption (Rhall, 2009). California, a state in the U.S was the first to enact a Green Building Code (CalGreen) and is poised to set the standard for greening of residential and commercial structures (Palmese, 2009). The California Public Utilities Commission has set the goal of all new homes meeting net-zero energy standards (producing as much energy as they use) by 2020, with commercial buildings required to meet the same goal by 2030. A study carried out by Kats and his team on 40 California LEED certified buildings showed great gains. There was a reduction in energy consumption, the buildings consumed 28% less than conventional buildings. Water consumption was cut by 50%, of the 21 green buildings studied, 17 reduced construction waste by at least 8% and 8 buildings reduced construction waste by 75%. Operational and maintenance cost were reduced by 5% an average of $3,000/person/year (Urban Catalyst Associates, 2005).

In Vancouver, research indicate that buildings are responsible for a significant proportion of the city's overall environmental impact contributing to 28% of greenhouse gas emissions, 30% of energy consumption, 12% of portable water consumption and 30-40% of landfill wastes (Vancouver Economic Development Commission, 2009). In 2005 the City of Vancouver passed a mandate that all civic buildings achieve LEED certification. Other policy development which are underway that will emphasize passive design techniques include; green roofs and increasing laneway housing by the year 2030. Vancouver also hosts local green energy expertise e.g. Nexterra which supplied biomass gasification system for Dockside Green, a greenhouse gas neutral residential development located in Victoria, British Columbia (Vancouver Economic Development Commission, 2009).

Green building activity and trends in Africa are slowly gaining recognition. Research shows that Green building is rapidly taking hold in South Africa, with its shares of firms that are dedicated to green building growing at a faster rate than any other part of the world (McGraw-Hill Construction, 2013). This suggests that there is a ripe real estate market in South Africa for green technologies, practices and solutions. In 2012, 31% of construction firms reported their work was green. Overall 16% of South Africa firms report high levels of green in 2012, an eightfold increase in just three years (McGraw-Hill Construction, 2013). South Africa is one of the only countries with a high reported level of green activity in residential marketplace. This indicate that fact that the growth of green building is occurring in tandem with increased urbanization in South Africa.

Research in Kenya of green building initiatives is rarely undertaken. That is why as a leader in innovation and knowledge dissemination, I have decided one of the most logical places to start researching, developing and implementing new green building technologies will start in my Country, Kenya and in particular Makongeni a place with great potential for real estate development.

2.2 Green Building Technologies and Fundamentals of Green Buildings

According to the LEED, the five major elements of green building design discussed in this study are: Sustainable Site Design; Water Conservation and Efficiency; Energy Efficiency; Environmental Improvement Quality; and Conservation of Materials and Resources (Rhall, 2009).Blending the right mix of green technologies that cost less with green technologies that cost the same or slightly more, it is possible to have a very green building project that costs the same as a conventional one. The key to a cost effective green building and site design lies within the interrelationships and associated cost and performance trade-offs that exist between different building systems (Governors Green Government Council , 2013).A good example is the interrelationships between the building site, site features, the path of the sun, and the location and orientation of the building and elements such as windows and external shading devices have a significant impact on the quality and effectiveness of natural daylighting. These elements also affect direct solar loads and overall energy performance for the life of the building.

2.3 Sustainable Site design

This involves engaging in a design and construction process that minimizes overall site disturbance and which values, preserves and restores or regenerates valuable habitat, green space and associated eco-systems that are vital to sustaining life. The layout and design of a building and site ground has an impact on energy and water consumption. A green planned site will preserve much of the existing natural vegetation, increase energy efficiency and reduce amount of storm water leaving the site (Environmental Science and Policy 763; UWGB, 2004). The amount of excavation required can be reduced, thus reducing construction costs and environmental impacts of the construction process. Key strategies and technologies that can be used include; renovating and re-using existing vacant sites and making efficient use of space in building already in occupational phase. Developers should steer clear of sites e.g. wetlands when new development is unavoidable.

Planners need to evaluate each site in terms of the location and orientation of buildings and improvements in order to optimize the use of passive solar energy, natural daylighting, and natural breezes and ventilation. Reducing the urban heat island effect of the site development footprint by maximizing the use of pervious surfaces, and using light colored roofs, paving, and walkways. Providing natural shading of buildings and paved areas with trees and other landscape features. Optimizing the use of on-site storm water treatment and ground water recharge at site. Minimizing the boundariesof the construction area, avoiding needless compaction of existing topsoil, and provide effective sedimentation and silt control during all phases of site development and construction. Once the construction phase is completed, landscape design should be used to preserve and restore the region’s natural habitat and heritage while emphasizing the use of indigenous, hardy, drought resistant trees, shrubs, plants and turf (Morrish, 2007).

2.4 Energy Efficiency

The goal of resource efficiency is to decrease utility bills but the ultimate goal is to save energy (Anderson, 1995). Current technologies and practices offer cost-effective opportunities to reduce energy use by 30-40% in new and existing buildings (Cohen-Rosenthal, 2000). Residential buildings produce large amounts of carbon dioxide and sulfur dioxide through the direct consumption of electricity and heating fuels. Lighting efficiency can be improved by replacing inefficient incandescent bulbs with new bulb models that have electrostatic ballasts and the use of natural lighting for illumination (daylighting). This can be achieved by using energy efficient T-8 and T-5 bulbs, high efficiency electronic ballasts, and lighting controls. Incorporating sensors and controls and design circuits so that lighting along perimeter zones or security light of the building can be switched off independently from other interior lights when daylighting is sufficient in perimeter areas (Governors Green Government Council , 2013).

Radiant solar heating is another energy efficient technology within a residential building. In this system dense tiles or concrete are used as flooring or as wall paneling. During the day the floors and walls absorb heat produced by the sun. As the building cools at night, the tiles release the heat energy retained from the day thereby there is no need for air conditioning. In passive lighting a green building would have many large windows that maximize the amount of light admitted into the building. Passive lighting works well with smart lighting; the two systems work together to reduce energy consumption while providing ample light to the occupants of the building. This not only reduces the building's energy demand by reducing reliance on electricity lighting but also provide better illumination of spaces. However shades should be installed to reduce direct sunlight penetrating the building (Rebecca Brownstone, 2004).

Smart lighting and power saving electronics are a simple way to save energy in a residential building. These devices are designed to shut down when not in use. Smart lights have photo sensors that read how much natural light is in the building and dim electric lights when there is substantial natural light. Smart lights are often equipped with motion sensors so that when there is no one in a room the lights automatically shut off (Rebecca Brownstone, 2004). Use Energy Star certified energy efficient appliances, and home equipment, lighting and HVAC (Heating Ventilation and Air Conditioning) systems. By optimizing the use of natural ventilation and where practical use evaporative cooling, waste heat and/or solar regenerated desiccant dehumidification or absorption cooling energy efficiency can be greatly increased. Home owners should also avoid the use of halogen based refrigeration, cooling and fire suppression systems (Governors Green Government Council , 2013). The benefit to smart lighting and power saving electronics is the reduction in overall energy consumption of the building thus a reduction in energy electricity costs.

The greatest challenge to all energy production is its impact on the environment. Solar power is one of the environmental friendliest ways of producing electricity or heating energy. In grid-connected systems, solar power has no effect on the environment, because the system does not include batteries that would need to be replaced (Rebecca Brownstone, 2004). Hot water is the largest component of residential energy cost after heating and cooling (Cassedy, 2000). A well designed water heating system will provide 50-80% of hot water needs depending on the building geographical condition and time of year. Solar water heating system heat water through thermal energy to produce hot water as illustrated in the figure below.

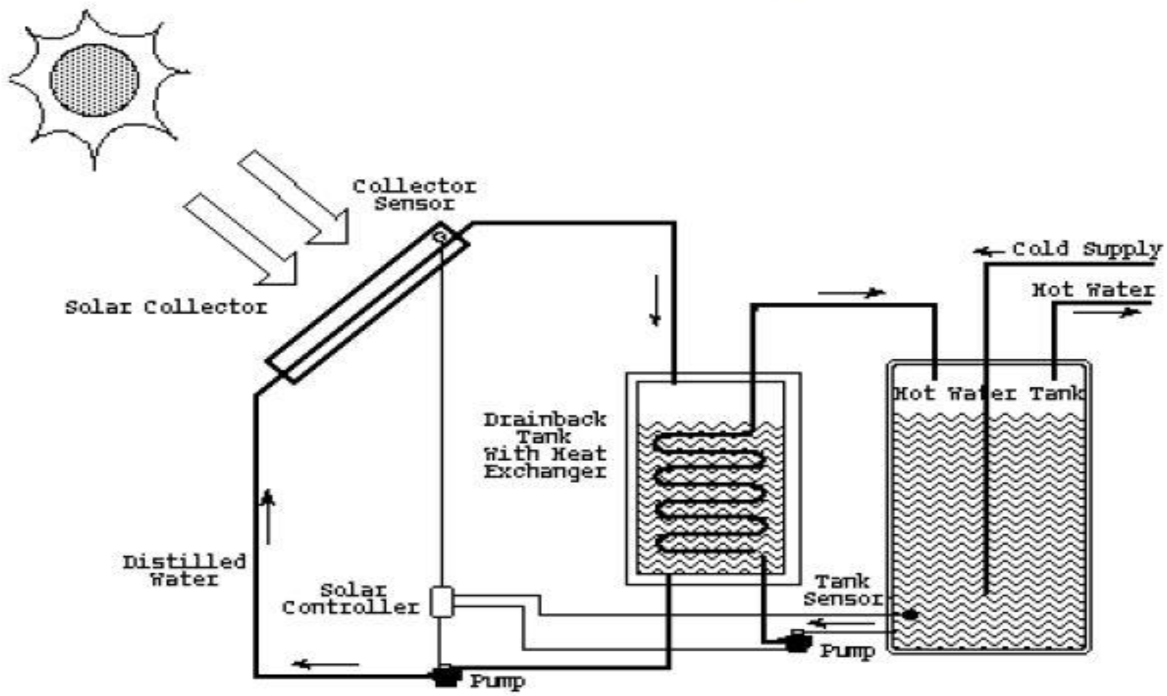

Figure 2: Solar Collector and water Heater.

(Source: City of Austin's Green Building Program, 1994)

Photovoltaic (solar panels) are green technologies incorporated into residential buildings by using the building's individual components i.e. building shell which includes energy efficient windows, lighting, insulation, foundation and the roof. Photovoltaic cells are mounted on the building in grid-connected pattern. The photovoltaic effect is a process in which two dissimilar materials in close contact produce an electrical voltage when struck by light or other radiant energy (Encyclopædia Britannica, 2013). They are noiseless, produces no emissions during operation and vary in size in a totally modular way (Rebecca Brownstone, 2004). This green technology is beneficial in that it reduces energy use by 50% or more, provide thermal insulation on the roofs, protect the roof from Ultra Violet radiation and reduces environmental footprint of the residential building.

2.5 Water efficiency

The major principle behind water efficiency is preserving the existing natural water cycle and design site and building improvements to emulate the site's natural "pre-development" hydrological systems. Emphasis should be placed on retention of storm water and on-site infiltration and ground water recharge using methods that closely emulate natural systems. Minimize the unnecessary and inefficient use of potable water on the site while maximizing the recycling and reuse of water, including harvested rainwater, storm water, and gray water (Governors Green Government Council , 2013).

During site assessment effort should be made to preserve areas of the site that serve as natural storm water retention and ground water infiltration and recharge systems. Preserve existing forest and mature vegetation that play a vital role in the natural water cycle by absorbing and disbursing up to 30% of a site's rainwater through evapo-transpiration. Optimizing the use of low-impact storm water technologies such as bio-retention, rain gardens, open grassy swales, pervious bituminous paving, pervious concrete paving and walkways, constructed wetlands, living/vegetated roofs, and other technologies that support on-site retention and ground water recharge or evapo-transpiration (Governors Green Government Council , 2013).

Water is often consumed with little or no consideration of the viability of water resources. Most areas of Makongeni face shortages in portable water supply. Increasing water efficiency can reduce water-supply and wastewater-treatment needs and their related costs (Houle Insulation Inc, 2013). The most basic start to water conservation is stopping leaks which account to up to 10% of the water wasted in residential homes. Installing water efficient toilets will result in significant water efficiency. Toilets represent a residential home largest water consuming device.

Using energy star certified washers with a water factor below 9.5 will use as little as half the amount of energy and water of a non-star washing appliance (California Urban Water Conservation Council, 2013). Dual-flush toilets should have two buttons that release different amounts of water for either liquid or solid waste should replace older models of toilets. These toilets use 6 liters for solid waste and 3 liters for liquid. The average flush volume is approximately 3.8 liters/flush compared to older models that use up to 13 liters/flush resulting in 67% savings in water.

A rainwater collection system is a simple green technology for the operation of a residential building to conserve water use. The rainwater is collected as it runs off the building and would be stored in cisterns until it is needed. The water can be used to water the rooftop garden, or treated for potable uses within the building (RainwaterHarvesting.Org, 2013). There environmental benefit of this technology is the reduction on load on municipal storm sewers and less demand on freshwater resources. Other green technologies used to conserve water and preserve ground water quality is by using only indigenous, drought resistant and hardy trees, shrubs, plants and turf that require no irrigation, installing waterless urinals and aerated faucets.

2.6 Green roofs

Green roofs are light weight, engineered roofing systems with low maintenance plants accessible as a rooftop garden that protect the integrity of the roof while at the same time providing many benefits such as storm water management and energy efficiency. Energy efficiency is ensured by the reduction in heating due to fewer fluctuations in roof temperature and insulating properties of vegetation. Green roofs also ensure extension of roof life through protection of the roof membrane from ultra violet radiation and the continued expansion and contraction due to fluctuating temperatures (Eisenman, 2004). Other benefits of green roofs are noise reduction, storm water retention taking load off municipal storm sewers during rainy season, improved air quality in the residential building and providing habitat for other organism e.g. birds, butterflies. Residential buildings with green roofs also have increased property values (Rhall, 2009).

2.7 Environmental quality, materials and resources

Providing a healthy, comfortable and productive indoor environment for building occupants and visitors through a residential building design, which affords the best possible conditions in terms of indoor air quality, ventilation, and thermal comfort, access to natural ventilation and daylighting, and effective control of the acoustical environment is the major principle behind this green initiative (Governors Green Government Council , 2013).

This green initiative can be achieved by use of building materials, adhesives, sealants, finishes and furnishings which do not contain, harbor, generate or release any particulate or gaseous contaminants including volatile organic compounds harmful to human health and wellbeing. Energy certified ventilation systems capable of effectively removing or treating indoor contaminants while providing adequate amounts of fresh clean make-up air to all occupants and all regions of the residential building. This appliances monitor indoor air conditions including temperature, humidity and carbon dioxide levels, so that building ventilation systems can respond when space conditions fall outside the optimum range.

Designing building envelope and environmental systems that not only treat air temperature and provide adequate ventilation, but which respect all of the environmental conditions which affect human thermal comfort and health, including the mean radiant temperature of interior surfaces, indoor air humidity, indoor air velocity, and indoor air temperature (Cohen-Rosenthal, 2000).

Preventing contamination of the building during construction involves taking steps to minimize the creation and spreading of construction dust and dirt. Prevent contamination of the building and the buildings heating, cooling and ventilation systems during the construction process. Protect construction materials from the elements so that they do not become damp, moldy or mildewed. The main essence of this initiative is to provide a clean and healthy building. Residents should use biodegradable and environmentally friendly cleaning agents that do not release harmful agents and residue. Prior to occupancy install new air filters in the HVACs and clean any contaminated ductwork and ventilation equipment. Use fresh outdoor air to naturally or mechanically purge the building of any remaining airborne gaseous or particulate contaminants (Governors Green Government Council , 2013).

Green buildings normally minimize the use of non-renewable construction materials and other resources through efficient engineering, design, planning and construction and effective recycling of construction debris. It also maximizes the use of recycled content materials, modern resource efficient engineered materials, and resource efficient composite type structural systems wherever possible. Maximize the use of re-usable, renewable, sustainably managed, bio-based materials. Key strategy and technology behind green material and resources is to identify ways to reduce the amount of materials used and reduce the amount of waste generated through the implementation of a construction waste reduction plan. Adopt a policy of "waste equals food" whereby 75% or more of all construction waste is separated for recycling and used as feedstock for some future product rather than being land filled. Implementing an aggressive construction waste recycling program and providing separate, clearly labeled dumpsters for each recycled material will ensure maximum resource efficiency (McGraw-Hill Construction, 2013).

Contractors should thereby identify ways to use high-recycled content materials in the building structure and finishes such as blended concrete using fly ash, slag, recycled concrete aggregate, or other admixtures to recycled content materials such as structural steel, ceiling and floor tiles, carpeting, carpet padding, sheathing, and gypsum wallboard. Green contractors go a step further and explore the use of bio-based materials and finishes such as various types of agri-board (sheathing and or insulation board made from agricultural waste and byproducts, including straw, wheat, barley, soy, sunflower shells, peanut shells, and other materials) (Governors Green Government Council , 2013). Some structural insulated panels are now made from bio-based materials. Use lumber and wood products from certified forests where the forest is managed and lumber is harvested using sustainable practices thus ensuring sustainable forest management practices.

Leadership in Energy and Environmental Design (LEED) is an internationally recognized green building certification system providing third party verification that a building or community was designed and built using strategies aimed at improving performance across all the metrics that matter most: energy savings, water efficiency, CO_2 emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts.

2.8 Environmental and social benefits of residential green buildings

Green buildings provide a healthy, comfortable and productive indoor environment for building occupants and visitors and the best possible conditions in terms of indoor air quality, ventilation, thermal comfort, access to natural ventilation and daylighting, and effective control of the acoustical environment as discussed in this study. A recent Lawrence Berkley National Laboratory Study reported that commonly recommended improvements to indoor environments could reduce health care costs and work losses from communicable respiratory diseases by 9-20 percent, among other benefits. By promoting the need and use of recycling construction material a lot of stress is alleviated from extraction and utilization of environmental resources thus conservation and reuse of materials and resources. As domestic fossil fuel supplies are depleted and energy resources getting expensive as each day passes, our nation becomes more dependent on sources from foreign countries. Energy-efficiency and renewable energy sources I green buildings can lessen this dependence and help improve national resource security (WaterFurnace International, 2011).

2.9 Financial Benefits of Green Buildings

Higher selling potential in the real estate sector due to health effects on inhabitants, durability and ease of maintenance, environmental friendliness, and energy efficiency associated with green buildings (Jeff Martin, 2007). Savings in energy of 20-50 percent are common through energy-saving technologies, integrated sustainable green initiatives. Increased value for developers and owners due to a growing confidence in the industry that a high-performance green building can either capture lease premiums or present a more competitive property in an otherwise tough market. Green buildings reduce the stretch on local infrastructure capacity.

Decreased energy and material requirements coupled with appropriate siting help stretch the capacity of overburdened public systems for grid supplied power, water, wastewater/storm water management (WaterFurnace International, 2011). Opportunities for investments from public equity markets should surge as greener building product comes to market for purchase and green product definitions become more standardized. The growing market acceptance of LEED as industry standards in more countries should help in this regard. Low utility bills due to energy and water efficiency brought about by incorporating green building technology and strategies.

3 CHAPTER THREE

3.1 Area of Study

This chapter gives the physical description of the project site in terms of position and size, topography, climate and soils as sourced from the District Development Plan of 2002-2008.

3.2 Location

The area of study is located in Thika Sub-County along the Garissa Road, behind Flame Tree Park Residential Housing units and opposite Thika Barracks, some 30km from Nairobi and some 10km to Thika town.Thus the site location is best described using Thika as a reference point. Makongeni is a residential and commercial town in Thika Sub-County. It is divided into different phases starting from phase 1-13 (Area of study being Phase 4). The area is serviced by an all-weather road from Thika Town (Garissa Road) and a seasonal road from Garissa Road to Makongeni Phase 4. High rise residential buildings are more predominant in the area of study though some family dwelling houses (bungalows) exist.

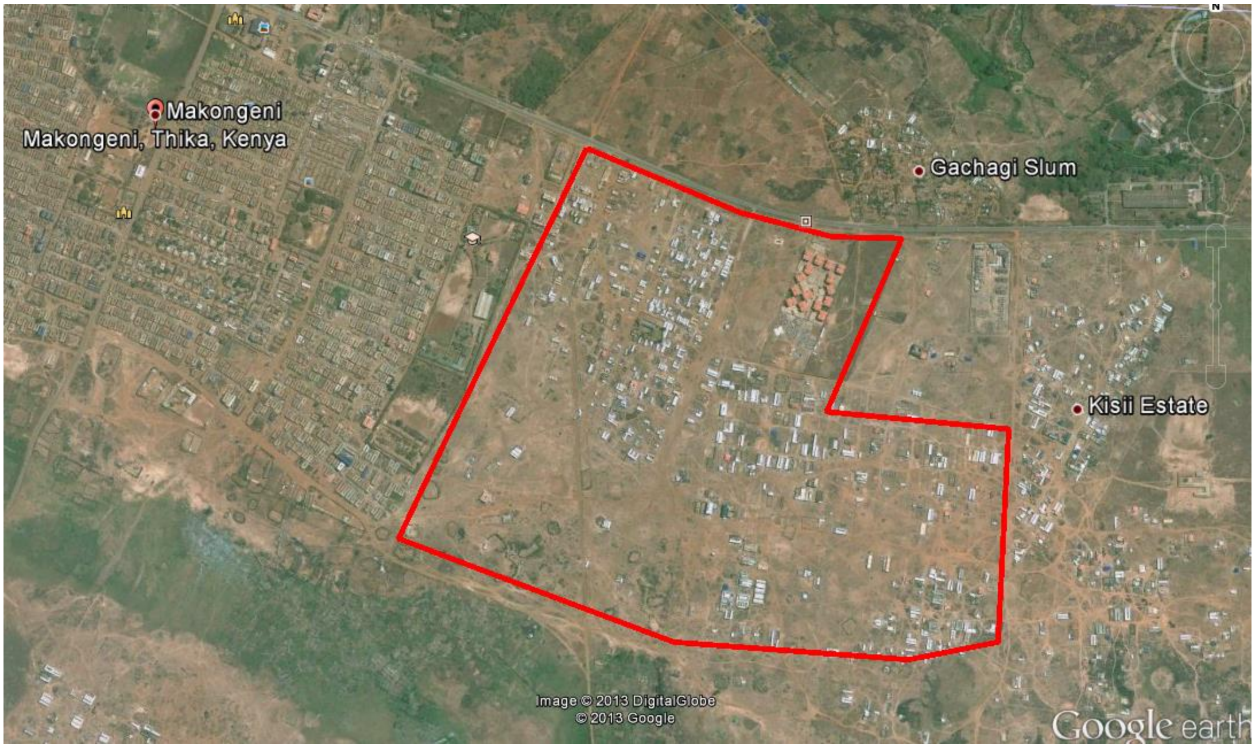

Figure 3: Area of Study.

Source: Google Earth, 2013

3.3 Topography

Makongeni lies between latitudes 3°53′ and 1° 45′ south of Equator and longitudes 36° 35′ and 37° 25′ east. The elevation of Thika is 1531 meters (5026 feet) in altitude. The landscape is generally level save for a few ridges and depressions in wetlands. Part of the study area land is a gentle slope with red clay soil with some sections bearing visible surface rock.

3.4 Climate

3.4.1 Average Daily Temperatures

The average daily temperature throughout the year (See Table 1 below) varies slightly from month to month with average temperatures of around 17 degrees Celsius during the months of July and August to about 20 degrees Celsius in March. But, the daily range is much higher, with the differences between maximum and minimum temperatures each day around 10 degrees in May and up to 15 degrees in February. Between the months of June to September, southeast winds prevail in the coastal parts of Kenya and last up to several days without a break. The clouds cause day temperatures to remain low and most times the maximum temperature stay below 18 degrees Celsius. The minimum temperatures also remain low during cloudy nights, usually hovering around 12 degrees Celsius. Clear skies in January and February also bring colder nights. The highest temperature ever reached in Thika is 22.4 degrees Celsius and the lowest was 3.9 degrees Celsius.

	Mean Maximum	Mean Minimum	Mean Range
Months	^{0}C	^{0}C	^{0}C
January	26.8	13.1	13.7
February	28.0	13.4	14.6
March	27.4	14.4	13.0
April	24.6	14.3	10.3
May	24.1	14.2	9.9
June	23.1	12.6	10.5
July	22.3	11.5	10.8
August	22.7	11.8	10.9
September	25.3	12.2	13.1
October	26.2	13.7	12.5
November	23.6	14.4	9.2
December	25.1	13.8	11.6
Year	24.9	13.3	11.6

Table 1: Average Daily Temperatures in Thika

3.4.2 Average Humidity Values

Due to Thika’s location just south of the equator (between 3^{o}53’ and 1^{0}45’) in combination with humid air pumped in from the Indian Ocean, the humidity values for each day are generally on the higher end.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
9.00 A.M	79	74	82	86	85	85	83	85	82	80	36	83
3.00 P.M	45	37	43	53	55	59	53	53	50	47	57	54

Table 2: Mean Relative Humidity Values (%)

This is not to say that values are always high, since the easterly winds coming off the Indian Ocean tend to keep the temperatures standard throughout the country; therefore the “warm sticky” feeling is usually not associated with Thika as much as one would think. In the summer to autumn months of January to April, relative humidity values have been known to plummet to anywhere from 10% to20%. The typical day, humidity-wise, starts off with nearly saturated in the morning hours, and steadily decreases throughout the remainder of the day.

3.4.3 Average Rain Amounts

With these routinely high relative humidity figures, it is not surprising that the Thika climate is one that produces much rain annually. In fact, from the past 50 years, the expected amount of rain could be anywhere in the range of 500 to 1500 mm, with the average ringing in at 900 mm. The majority of these rainfall figures crash down in Thika in one major and one minor monsoon seasons respectively. The major monsoon season occurs within the months of March to May, and locally referred to as the “Long Rains” by the locals. The minor monsoon seasons emerges within the October to December Months, and is called the “Short Rains”. That is what the meteorologists as a whole know about the monsoon season. What they do not know is exactly when these seasons will start. There is usually not an indication of when these rainy seasons will start, since it is difficult to determine when one starts and when the other finishes. Consequently, a person may think there is only one rainy season when looking at the annual rainfall amounts.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
48	48	115	195	137	42	15	21	24	52	114	77

Table 3: Average Rainfall (mm) for each Month of the Year, based on the records for 50 years

3.4.4 Average Winds

Winds along the surface are predominantly easterly throughout the entire year. They are shifted to northeast between October and April, and they are shifted southeast between May and September.

Right before the “Long Rains” season, the strongest winds occur, reaching speeds of 20 to 25 miles per hour. During the rest of the year, winds are usually at speeds of 10 to 15 miles per hour. During the night, the winds are calm.

3.4.5 Average Sunshine

Early mornings in Thika are often cloudy, but the sun peeks through by early mid-morning.

Throughout the year, there is an average of ten hours of sunshine per day. More sunlight reaches the ground during the afternoon than in the morning. Of course, there is more sunshine during the summer months, when the sun is more overhead in the southern hemisphere. Very rarely during the rainy season the sun never shows through the clouds. Even in August, the cloudiest month, there is a period of some hours of sunshine.

3.5 Soils and Geology

In Thika District in general, the rocks exposed consist of horizontal Tertiary lavas, pyroclastics and sediments in the west, and folded Basement System gneisses and schists to the east. The Basement System rocks are metamorphic, and have been in places granitized to a considerable degree, with the production of granitoid gneisses. Soil types in the area are dependent on drainage; black-cotton soils develop in poorly drained regions while sandy soils and murrams form in well drained regions. The proposed project area consists of red soils suitable for farming and brick-making.

4 CHAPTER FOUR: RESEARCH METHODOLOGY

4.1 Introduction

Methodology is generally a guideline for solving a problem with specific components such as tasks, methods, phases, techniques and tools. It can be qualitative or quantitative. Methodologies encompass procedures followed, analyze and interpret the data gathered. This chapter therefore describes the methods and procedures likely to be used during the study, most significant in achieving the set research objectives and goals as per the requirement of the study.

4.2 Key Subjects

The principle subjects of this study process who are the primary source of our data. They will involve:

4.2.1 Local Community

This will involve the residents and tenants in area of interest (AOI). This will include locals who reside in the area of study.

4.2.2 Local Administrators (Chiefs, County representatives, women representatives)

It is necessary to inform the area's administrators of my research survey and include them in my survey. The local administration will help in providing crucial information such as demographic statistics among others.

4.2.3 Contractors

Contractors will play an important role in providing data relevant to my research study such as type of building construction materials, building designs and schematics and available green technologies in the market.

4.3 Research Design

This research study will employ a descriptive survey design by utilizing a number of techniques to meet the objectives of the study. The methodology will entail collection of both primary and secondary data from the field and other sources respectively.

4.3.1 Primary Data Sources

Primary data sources will include observation, questionnaires, interviews, and photography. Types of building designs within the area of interest will be observed and noted. Other primary data will be sourced from the Thika Sub-County and relevant government departments.

4.3.1.1 Primary data collection techniques

4.3.1.2 Sampling

Simple random sampling technique will be employed to select the households while systematic sampling will be used to select the various organizations relevant to our research.

The data collection techniques that shall be employed in addition to library research will involve the following:

4.3.1.3 Written Questionnaires:

Well-structured questionnaires will be administered to various respondents/ stakeholders. These will be answered in written form by the various respondents. A questionnaire is a research instrument consisting of a series of questions and other prompts for the purpose of gathering information from respondents. Structured questionnaires were used to collect population data (structure and sex ratio), education levels, energy sources, energy use, Municipal services, and income levels among other parameters.

Type of questionnaires to be used will include both open and closed questionnaires. Closed questionnaires will include questions with "Yes/No" answer or with a multiple choices. Answers that will be selected in the quality control check stage will be used to develop possible proposals.

4.3.1.4 Oral Interviews

- This technique will involve data collection through questioning respondents especially landlords, tenants and contractors from various office establishments within Makongeni.
- **Scheduled Interviews**: Schedules for interviews will be prepared for stakeholders like Thika Sub County, Thika Water and Sewerage Company, Kenya Power and other identified institutions that deal with real estate development.
- **Photography**: Photographs of the study area will be taken. Photography will focus on various areas involved in residential development. These will be used during the analysis

of current situation in Makongeni and other areas in relation to other Green design infrastructural development.

Open ended questionnaires will include answers from the respondents unlike in closed questions where the questions have specified answers.

4.3.2 Secondary data sources

This will include information about sustainable green building designs both published and non-published information will be used.

Secondary information will also be used to provide a strong background to the study area by informing on the existing residential design technologies.

Data to be used will include satellite imagery, existing reports, topographical sheets and from relevant academic sources.

4.3.2.1 Instruments of secondary data collection

Secondary data will be collected by carrying out intensive library research and online internet resources. The review of literature will include looking at

- Documents and journals on Green Building Designs and Technologies
- Various case studies on Green Building Designs and Technologies.

4.3.3 Data Processing and Analysis

4.3.3.1 Methods of Data Analysis and Presentation

Qualitative and quantitative methods will be incorporated to analyze the information gathered from the respondents through calculation of means, percentages and even mode. Respondents' expressions and perceptions, events, questionnaires, behavioral observation, records will be analyzed. Percentages, proportions and averages will be employed to reach the conclusions. Data presentation will be done through pie charts, graphs, photographs and maps.

Processing and analysis will involve:

4.3.3.1.1 Sorting data

This will entail ordering of questionnaires and other field records for the purpose of subsequent processing and analysis. The questionnaires will be numbered and arranged systematically.

4.3.3.1.2 Quality control check

This will involve analysing the validity and feasibility of data collected using various selective criteria.

4.3.4 Variables

4.3.4.1 Dependent variables

The outcome variable (dependent) was green building technology.

4.3.4.2 Independent variables

The predictor variables of the study included energy efficiency measures, water efficiency measures, material resources utilization and indoor air and wellbeing quality.

4.3.4.3 Target population

The target population consisted of household heads/spouses in the study area.

4.3.4.4 Study population

The study population consisted primarily of household heads/ spouses in the selected households in the selected households who have been residents in the study area.

4.3.4.5 Sampling technique

Purposive sampling was deployed to the selected study area. Cluster sampling was used to identify the various blocks that were included in the study area. A block in Makongeni Phase 4 was signified as a cluster. The area of study was subdivided into six blocks for ease of administration with each block forming a cluster. Two clusters were selected randomly out of the six blocks. Simple random sampling was used to select households that were included in the study to yield 50 respondents.

4.3.4.6 Sample size calculations

The sample population for the study included all permanent occupants in recruited buildings. In the case of academic office buildings, 'permanent' referred to full time graduate students and staff. Initial contact with potential subjects was done through an email invitation, with names and addresses provided by building administrators, and those who agreed to participate were then given the option to complete the online survey. Building users were surveyed using the Building Use Studies (BUS) occupant questionnaire (Usable Buildings Trust, 2010) slightly modified to include occupant knowledge about various green technologies in building designs.

According to (Czaja, 1996), sample size calculations with a finite population correction were used to establish target response rates (Equation I).

$$n = \begin{matrix}\text{finite}\\ \text{population}\\ \text{correction}\end{matrix} * \frac{\text{probability level * variance}}{\text{confidence interval}} = \left(1 - \frac{n}{N}\right) * \frac{t^2\,(p*q)}{d^2}$$

Equation 1: Sample size calculation for a finite population

Where: n = The sample size or number of completed surveys

N = The size of the eligible population

t^2 = The squared value of the standard deviation score that refers to the area under a normal distribution of values

p = The percentage category for which we are computing the sample size

q = 1-p

d^2 = The squared value of one half the precision interval around the sample estimate

Response rates were 86% for the study (confidence interval (C) = 0.06).

	Sample size assuming large population	Actual population at time of survey	Sample size with finite population correlation	Number of responses	Response Rate	Confidence Interval
Overall results	50	46	46	42	86%	0.06

Table 4: Response Rates and Confidence Interval

Average response rates for the BUS questionnaire are around 80% however this refers to hand delivered paper-based surveys. Response rates for web-based surveys are typically lower. CBE reports response rates ranging from 27% - 88%, with the majority of response rates between 45% and 65% and the mean at just over 50% (Zagreus, 2004).

4.3.5 Logical and Ethical considerations

The target households in the study area were given adequate explanation on the purpose of the study. Respondents were given time to seek clarifications and/or ask questions before being recruited into the study. Difficult questions in the questionnaire were simplified and Informed consent was sought from the sample population before conducting interviews. Participation for the study was fully voluntary and confidentiality was maintained at all levels during the study.

4.3.6 Instruments and methods

4.3.6.1 Construction and research instruments

Two types of instruments were used to collect data including an interview schedule/face to face interviews and questionnaire method. Structured interview schedules were administered to respondents to collect quantitative data. Questionnaire guides were used to collect in depth information from respondents regarding their knowledge of green building technology, applicability and usability in their places of residence.

4.3.7 Data Quality Measures

4.3.7.1 Validity

Cluster and simple random sampling were used to select blocks (clusters) included in the study. Simple random sampling was then used to obtain the desired sample size. Random face to face interviews and structured questionnaire were used to collect data in the area of study. All the research instruments were pretested before the actual study.

4.3.7.2 Reliability

The research assistants were trained prior to actual data collection to ensure they collected the desired data. For accuracy the researcher accompanied each group on alternate days. All used research tools were counterchecked by the researcher at the end of each day for any mistakes and errors.

5 Chapter 5: Data management, data analysis and discussion/interpretation

5.1 Introduction

The quantitative data was coded and entered into a computer database designed using Statistical Package format (SPSS 16).

5.2 Data analysis

Data analysis was conducted using SPSS statistical software. Exploratory data techniques were used at the initial stage of analysis to uncover the structure of data and identify outliers or unusual entered values. Quantitative data was coded and processed using SPSS version 16.0. Descriptive statistics such as frequencies, standard deviation and means were used to summarize, organize and simplify the data collected. Correlation analysis was employed to test the relationship between dependent and independent variables. A significance level of 0.06 was used. Quantitative data was presented using frequency tables and graphs while qualitative data was used to reinforce the quantitative data.

5.3 Data results

According to the survey results most of the household involved in this study were owner occupied 58% with rental residences accounting for 42%. Male headed and managed households accounted for 60% of the total respondents while male headed but female managed households accounted for 18% and female headed and managed households accounted for 16% of the respondents who participated in the study.

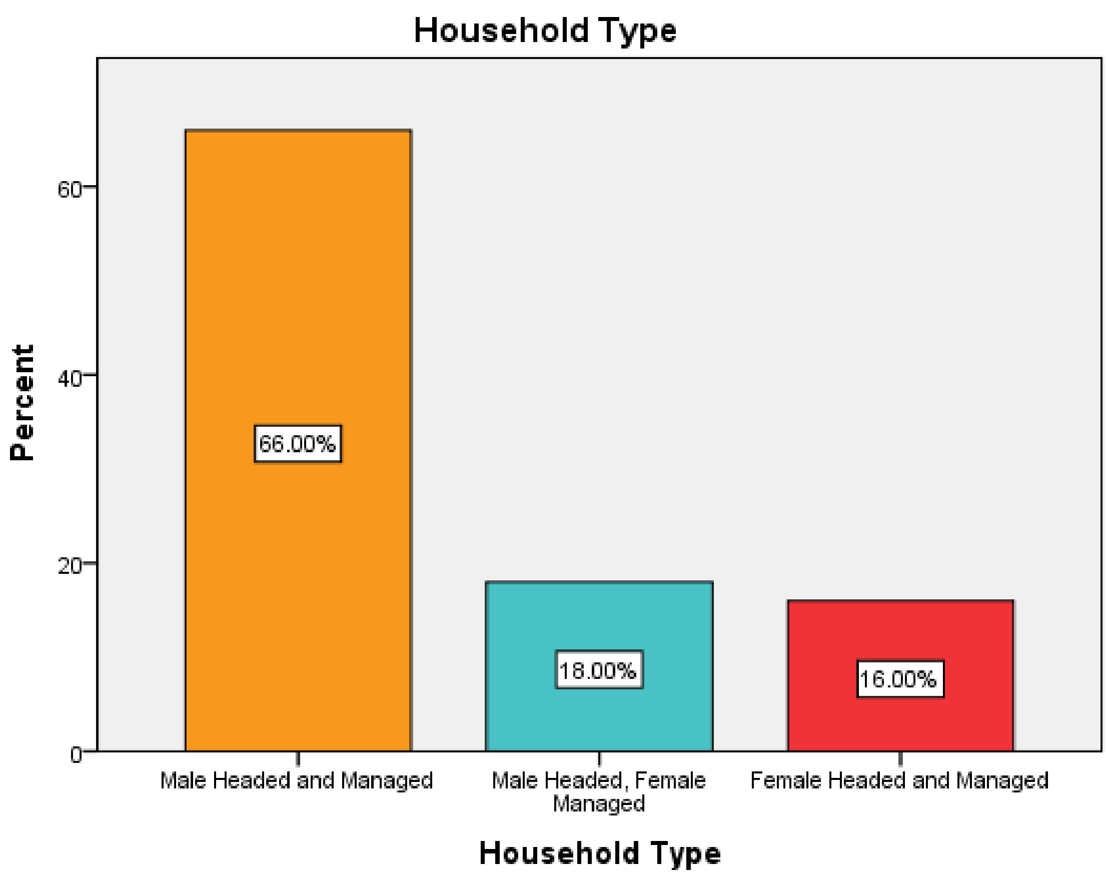

Figure 4: Household Type

5.3.1 Occupant satisfaction

Results from the questionnaire indicate that occupants in the study area were fairly satisfied overall with the building design and its ability to meet occupant's needs. Satisfaction in design overall was rated at 38-44%. Occupant satisfaction with use of space in the building was the highest at 65%. The ability of the building facilities to meet occupants' needs for work, and effective use of space in the building both had satisfaction ratings close to 72%.

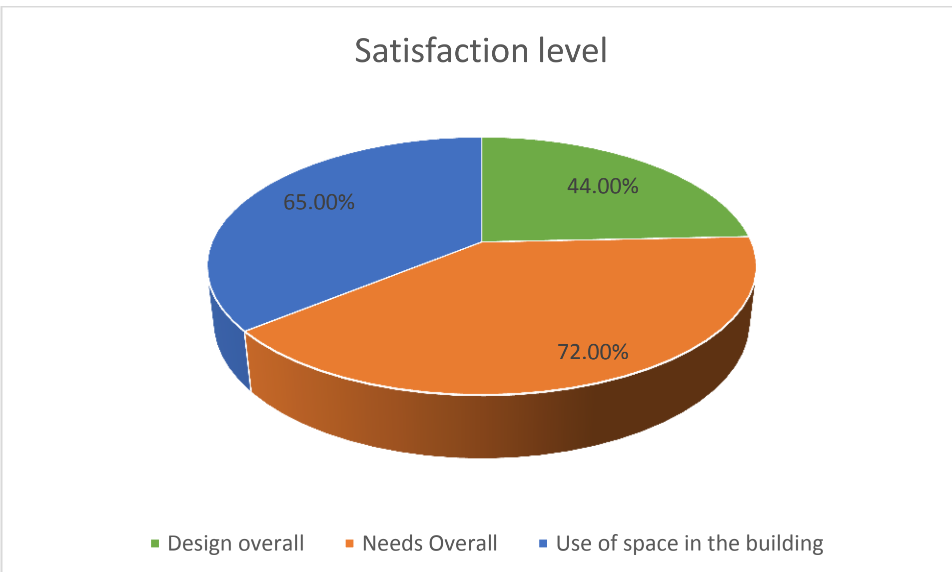

Figure 5: Satisfaction Level for Building Design Overall, Needs Overall, Space

Respondents pointed to building design issues related to temperature and ventilation, fragile building facilities many of which had broken, an insufficient number of washrooms, a lack of access to drinking water in some residencies, and poor sound isolation from the immediate surrounding environment.

Further, respondents were asked for their perception of the degree of 'greenness' of the building. 2% of respondents thought the building was a green building, 98% did not think it was a green building. Those who responded 'Yes' compared the building with other less green buildings, referred to visible green features and strategies they had personally observed, and referred to specific things they had heard about a green building. After explaining to a majority of respondents about what a green building is sample responses were as follows:

• 'I think the building is energy efficient'

• 'Low-flow/water-free washrooms. Energy efficient lighting. Presence of solar panels on the roof'

• 'Solar panels, glass, recycled materials.'

Respondents who responded 'No' had very specific definitions of what they considered to be green. They pointed mostly to wasted energy or materials in the building. Sample responses were as follows:

- '"Green" building is a building that does not have significant ecological footprint on the neighboring environment.
- 'Some green functions had to be replaced (low-flow toilets); others still do not work correctly (air cooling functions).
- Failure of automatic light function means people leave lights on.'

Figure 6: Green Building Knowledge (%)

5.3.2 ENERGY PROVISIONS

5.3.2.1 Lighting/cooling provisions

Respondents in the study were asked to rate the building in terms of energy efficiency. 64% of the respondents rated the building “very well”, 20% rated the building “very poorly” with 16% of the respondents rating their building “Fairly”. These ratings were attributed to the amount of energy consumption per month the building occupants consumed with 34% of the respondents paying 501-1000 shillings in their monthly bill.

5.3.2.2 Energy Consumption per Month

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-200 Ksh	7	14.0	14.0	14.0
	201-500 Ksh	13	26.0	26.0	40.0
	501-1000 Ksh	17	34.0	34.0	74.0
	1001-2000 Ksh	8	16.0	16.0	90.0
	> 2000 Ksh	5	10.0	10.0	100.0
	Total	50	100.0	100.0	

Table 5: Energy Consumption per Month

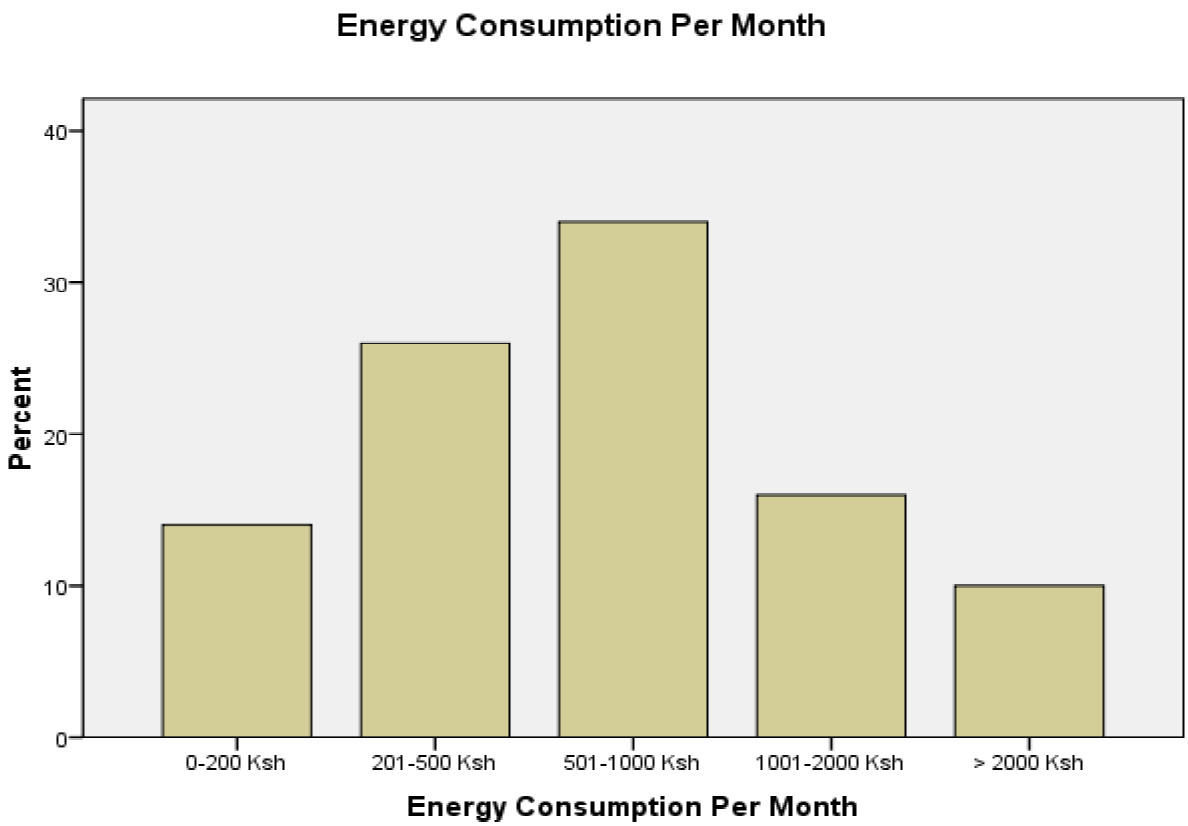

Figure 7: Energy Consumption per Month

5.3.2.3 Energy Efficiency * Energy Consumption Per Month Crosstabulation

			Energy Consumption Per Month					
			0-200 Ksh	201-500 Ksh	501-1000 Ksh	1001-2000 Ksh	> 2000 Ksh	Total
Energy Efficiency	Very Poorly	Count	0	8	2	0	0	10
		% within Energy Efficiency	.0%	80.0%	20.0%	.0%	.0%	100.0%
	Fair	Count	0	0	4	1	3	8
		% within Energy Efficiency	.0%	.0%	50.0%	12.5%	37.5%	100.0%
	Very Well	Count	7	5	11	7	2	32
		% within Energy Efficiency	21.9%	15.6%	34.4%	21.9%	6.2%	100.0%
Total		Count	7	13	17	8	5	50
		% within Energy Efficiency	14.0%	26.0%	34.0%	16.0%	10.0%	100.0%

*Table 6: Energy Efficiency * Energy Consumption per Month Cross tabulation*

Respondents in the study were further asked about the amount of day lighting duration the buildings receive 50% of the respondents responded it was adequate, 20% responded the building received excess day light exposure mainly due to the orientation of the building in relation to the position of the sun. 15% of the respondents responded the building received limited day light. The response was the same when the respondents were asked about natural light exposure as shown in the table below

5.3.2.4 Natural Light Exposure

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Adequate	25	50.0	50.0	50.0
	Too Much	10	20.0	20.0	70.0
	Limited	15	30.0	30.0	100.0
	Total	50	100.0	100.0	

Table 7: Natural Light Exposure

As for artificial light exposure the responses were quite varied as compared to day lighting exposure and natural light exposure as indicated in the table below.

5.3.2.5 Artificial Light Exposure

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Adequate	24	48.0	48.0	48.0
	Too Much	11	22.0	22.0	70.0
	Limited	15	30.0	30.0	100.0
	Total	50	100.0	100.0	

Table 8: Artificial Light Exposure

Respondents in the study were the most knowledgeable about lighting and fresh air provision, two comfort variables that are both familiar in terms of control (switching lights on and off), and tangible in terms of performance (sensing fresh air). Most respondents were less knowledgeable about heating and cooling. Response for heating provision (mechanical heating combined with natural/passive) was submitted by all respondents, respectively. However, 70% thought that heating was provided by Natural/Passive system and 20% did not know how heating was provided. Response for cooling provision (mechanical cooling) was submitted by 100% of respondents, while 100% of the respondents thought that cooling was natural passive system. As for lighting the response results were significantly higher with a response rate of 98%. 65% of the respondents thought that lighting was provided electrically (electric bulbs), 25% thought lighting was provided though Natural/Passive means (windows and blinds) while 10% did not respond.

5.3.2.6 HEATING AND COOLING PROVISION

5.3.2.6.1 Heating Provision

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Natural/Passive	35	70.0	70.0	70.0
	Don't know	10	20.0	20.0	90.0
	88	5	10.0	10.0	100.0
	Total	50	100.0	100.0	

Table 9: Heating Provision

5.3.2.6.2 Cooling Provision

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Natural Passive System	50	100.0	100.0	100.0

Table 10: Cooling Provision

Buying of energy saving bulbs identified as the major energy reduction measure by most respondents (52% on average). Turning off lights and appliances not in use accounted for 48% of the responses of energy reduction measure. Most buildings did not have provisions for renewable energy technologies according to responses from 86% of respondents. Most respondents (36%) used energy certified star appliances compared to 28% who did not and 28% who had no idea if the appliances they used were energy star certified.

According to the survey results, most buildings did not utilize energy efficient lighting controls such as occupancy sensors as well as daylight sensors (54%). Most owner occupied buildings had installed daylight sensors that automatically controlled perimeter lighting.

5.3.2.7 Energy Sensor Regulation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	12	24.0	24.0	24.0
	No	27	54.0	54.0	78.0
	I don't know	6	12.0	12.0	90.0
	No Answer	5	10.0	10.0	100.0
	Total	50	100.0	100.0	

Table 11: Energy Sensor Regulation

In Buildings designs in the study area, temperature, air quality, and noise ranked statistically lower, and lighting was the only highly ranked variable.

Thermal conditions in the building designs were perceived to be hot in the especially during the dry summer season (January) with air conditions that were too still and too dry. Overall, 74% of respondents were dissatisfied with temperature and air in their respective occupational building.

Respondents were evenly spread in their rating of satisfaction with noise overall in the building, with 66% satisfied and 24% dissatisfied. Complaints for noise related to high sound transmission due to loud music and entertainment, a lack of privacy, and hallway noise from people having conversations and talking loudly on mobile phones.

82% of respondents were satisfied with overall lighting conditions, which was statistically higher than temperature, air quality and noise levels. Occupants were particularly satisfied with this aspect of the building design.

Occupants located in core spaces of the building especially multi-storied floors complained about lack of windows and natural light.

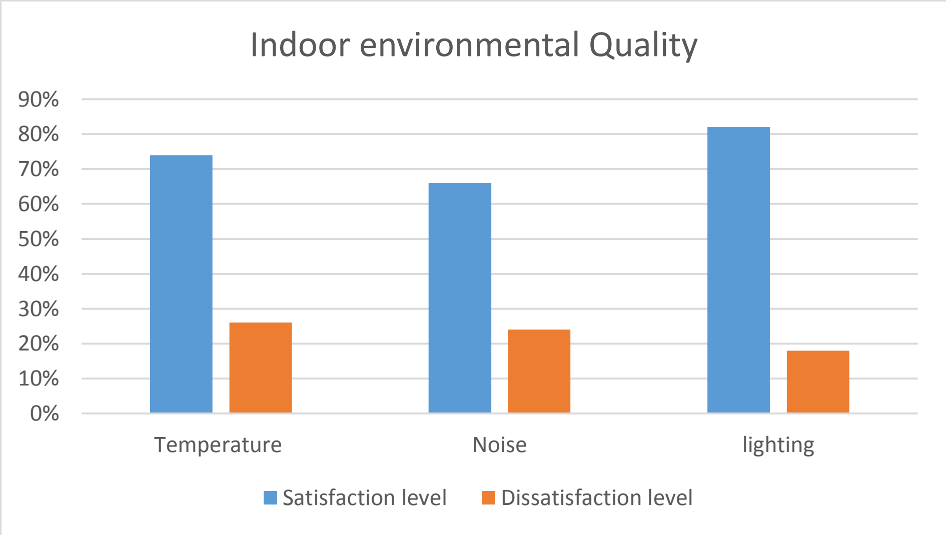

Figure 8: Indoor environmental quality

5.3.2.8 Personal control

Respondents perceived less personal control on average over the indoor environment despite the fact that the only significant identifiable different in quantity of personal control was lighting on most buildings.

Figure below shows the range of personal control (from no to full control) perceived for each comfort variable, with lighting ranking the highest, followed by ventilation, noise, cooling and heating. The ranking of personal control is in part a reflection of the actual availability of controls in the buildings, with lighting switches and operable windows (ventilation) being the most widespread and accessible environmental control systems in most building in the study area.

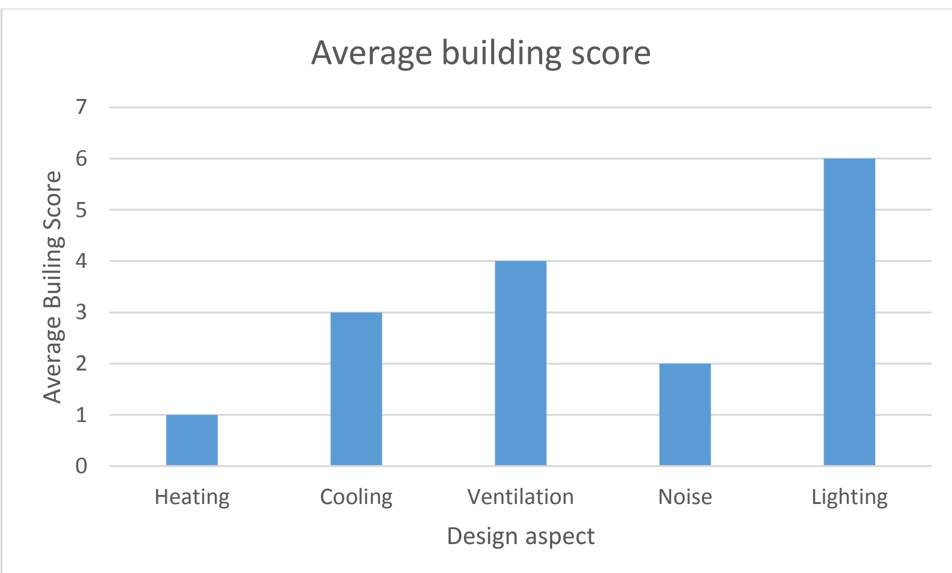

Figure 9: Average building score

A total of 14% of respondents said they used personal controls once a day or more mainly attributes to lighting controls, 25% said several times a week, and 10% said once a week. 43% of respondents have never used personal controls.

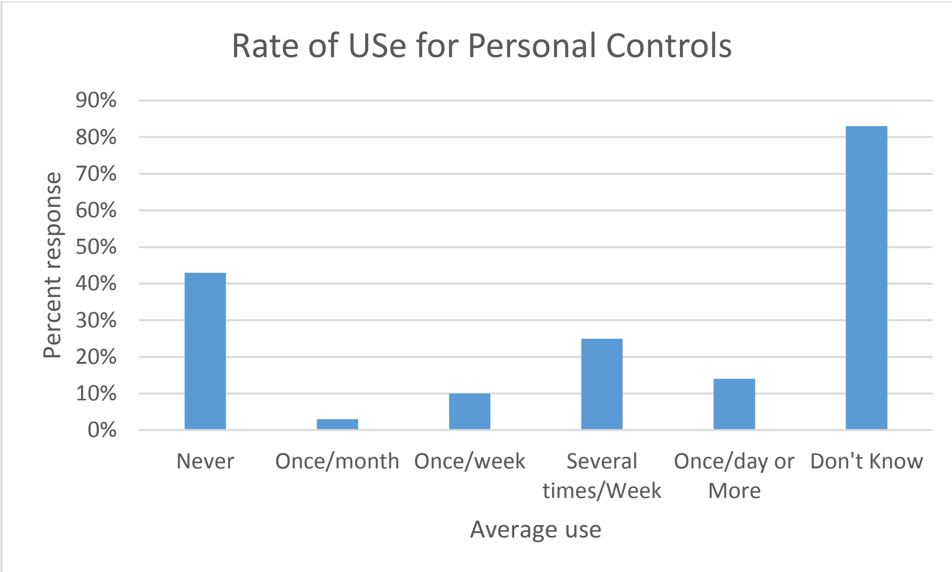

Figure 10: Rate of use personal controls

When respondents were asked to explain why they did not use personal controls, the highest reason given (after 'controls don't exist 84 %') was 'I don't know what they are 8%" followed by 'I don't know how to use them 8%'. (Figure 10)

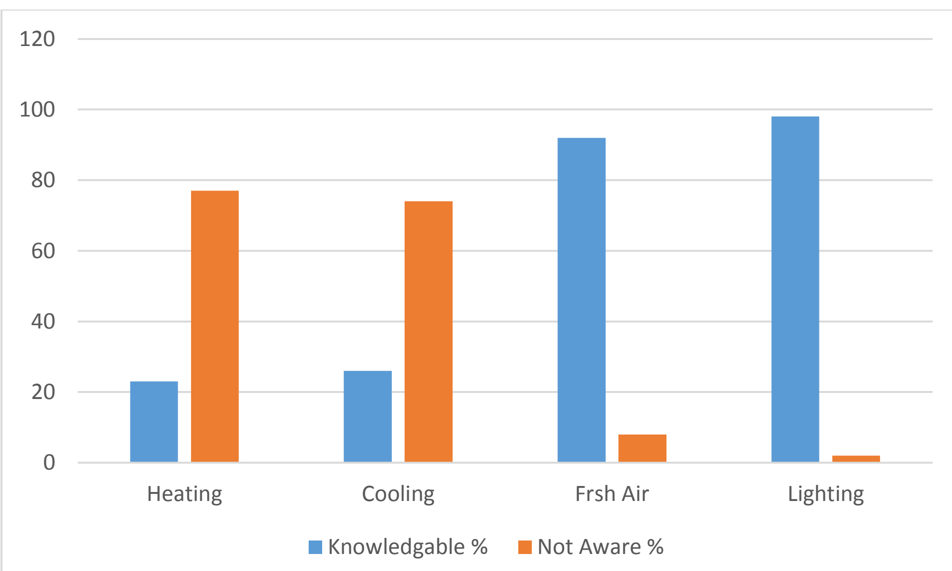

Figure 11: Occupant knowledge about specific environmental control systems.

Results from the knowledge section of the questionnaire suggest that the method used to assess respondents understanding of green building technology and environmental control systems relative to expert baseline was perhaps less accurate than hoped, in that the building expert's perception of comfort provision was equally as subjective as the respondent's perception. For instance, to the respondent, the window was perceived as a source of both fresh air and cooling, whereas to the building expert, the window was seen as a form of comfort control rather than comfort provision.

5.3.3 Water efficiency

5.3.4 Water consumption per month

Respondents in the study were asked about their water consumption per month. 54% of respondents used over 80 liters of water, 34% used between 61-80 liters of water with 12% consuming 41-60 liters of water per month. Higher water consumption was attributed to lack of high efficiency and innovative plumbing fixtures and fittings. Toilets were determined to consume the greatest amount of water in the house with every flush attributing to more than 10 liters of water used. Most building lacked WaterSense labeled modern toilets that reduce water consumption.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	41-60 Liters	6	12.0	12.0	12.0
	61-80 liters	17	34.0	34.0	46.0
	Over 80 liters	27	54.0	54.0	100.0
	Total	50	100.0	100.0	

Table 12: Water consumption per Month

5.3.4.1 Use of water efficient Fittings/Fixtures

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	17	34.0	34.0	34.0
	No	11	22.0	22.0	56.0
	4	22	44.0	44.0	100.0
	Total	50	100.0	100.0	

Table 13: Use of water efficient fittings/Fixtures

When the respondents were asked if they used water efficient fittings/fixtures 34% answered yes, 22% answered no and 44% did not have a clue as to what this innovative fixtures were.

5.3.4.2 Use of individual Meter Units

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	18	36.0	36.0	36.0
	No	2	4.0	4.0	40.0
	I Don't Know	30	60.0	60.0	100.0
	Total	50	100.0	100.0	

Table 14: Use of Individual Meter Units

Respondents were asked whether they used individual meter units to monitor their water consumption. Overall, respondents did not know if or not they had meter units in the buildings (60% on average), 4% answered No, with 36% answering Yes, mostly those who lived in owner occupied buildings.

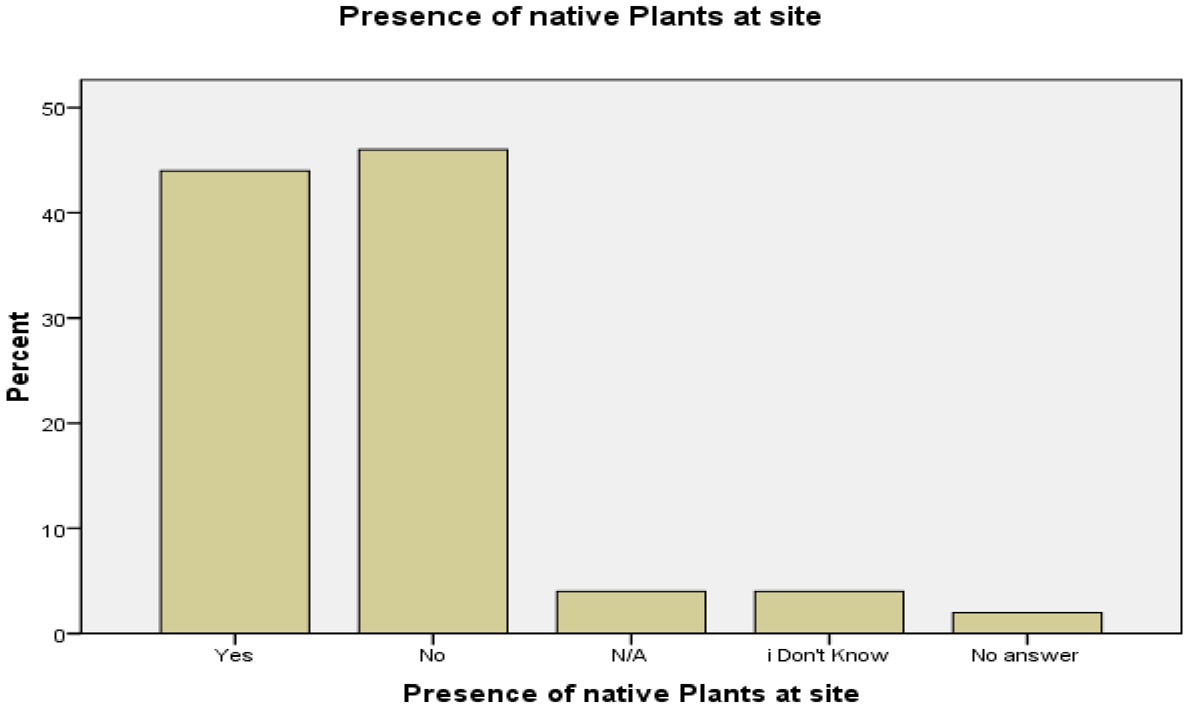

Figure 12: Presence of Native Plants at Site

Rainwater harvesting was practiced by most respondents especially those who lived in owner occupied buildings during the rainy seasons (58% on average). 40% of the respondents did not practice rain water harvesting especially those who lived in rental building due to lack of rainwater fetching equipment. Presence of native plants was marginally higher with 44% of the respondents having grown them in their compounds. 46% of the respondents did not have any idea of what these native plants were neither having grown them as a water consumption saving strategy.

5.3.4.3 Innovative waste Water Technologies

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	12	24.0	24.0	24.0
	No	29	58.0	58.0	82.0
	N/A	4	8.0	8.0	90.0
	I Don't Know	5	10.0	10.0	100.0
	Total	50	100.0	100.0	

Table 15: Waste water technologies

Based on the survey results, 58% of the respondents did not use an innovative waste water technology i.e. waste water treatment plant incorporated into the building to reduce generation of waste water and portable water demand. 24% of the respondents had innovative waste water technology especially those on owner occupied buildings with 9% having no idea what waste water technology was incorporated into the building.

The major reason given as to why respondents did not incorporate waste water treatment plants was the high cost of construction and maintenance budget and the apparent lack of space. Waste water was mostly directed towards the septic tanks or disposed as runoff.

5.3.5 Health and wellbeing

5.3.5.1 Overall Stress Levels

Respondents were asked whether they felt more or less stressful when in the building compared to their experience of using other buildings in general. Overall, respondents felt less stressful (52% stressful on average) and rated their overall sense of wellbeing higher (58% improved on average). Factors that lead to less stress levels were given by the respondents as better air quality, improved moods from access to sunlight and a general ‘feeling’ that health and wellness are more of a priority in the new building.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Stressful	12	24.0	24.0	24.0
	Can Cope	26	52.0	52.0	76.0
	Not Stressful At All	12	24.0	24.0	100.0
	Total	50	100.0	100.0	

Table 16: Overall stress Levels

5.3.5.2 Overall Sense of Wellbeing

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Poor	5	10.0	10.0	10.0
	Fair	16	32.0	32.0	42.0
	Very Good	29	58.0	58.0	100.0
	Total	50	100.0	100.0	

Table 17: Overall Sense of Wellbeing

Based on survey results, occupants are less satisfied with the building overall in terms of its design, image, and ability to meet their needs mainly those on rental buildings as they had no influence on the building design. Satisfaction ratings for these variables ranged from 4 – 7%.

Survey results indicate that air quality, lighting quality and comfort overall were rated highly in the with satisfaction levels ranging from 74 – 92%. Both lighting quality (98% satisfaction) and air quality (84% satisfaction), while comfort overall (56% satisfaction).

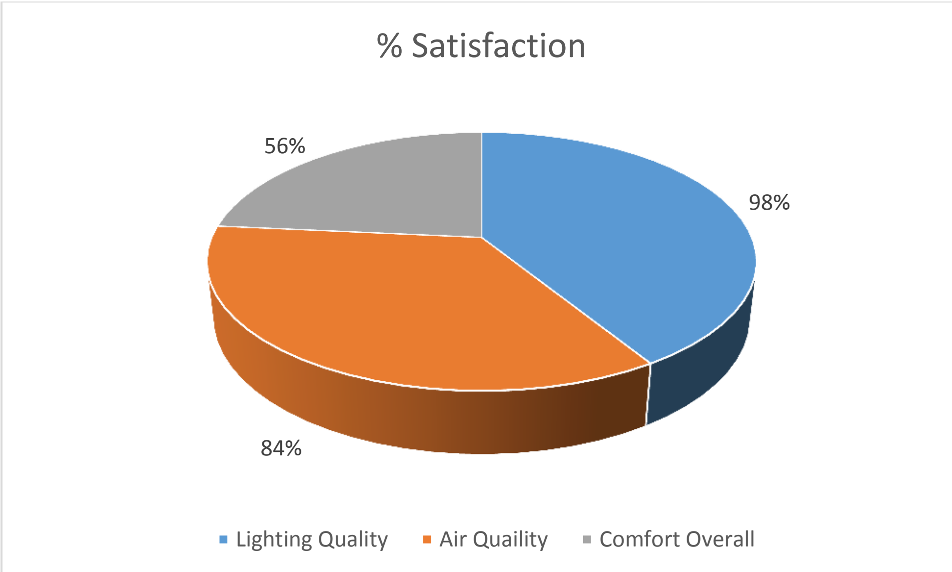

Figure 13: Satisfaction levels for Lighting, Air and Comfort (%)

Comments given during face to face engagement on thermal comfort mainly had to do poor understanding of occupant control over temperature. However, thermal comfort did not appear to have as great an impact on productivity as some of the other indoor environmental variables.

Respondents cited the beautiful design of the building, spaciousness, the abundant fresh air and natural lighting. A concern with regards to health in the building again had to do with air quality issues arising from the sewage system.

Sample comments from respondents:

- The building is great for the most part although the temperature can be quite uncomfortable during the hot days.
- Lack of temperature controlling mechanisms in the building and poor understanding of occupant control over temperature.

5.3.6 Air Quality

5.3.6.1 Rate Indoor Air Quality

Occupant satisfaction with overall air quality was around 76%, with satisfaction with both air movement and freshness (i.e. 'stuffiness') was significantly better. Respondents found the quality of the air to be fresh year round, with good air circulation – although at times respondents complained of air degeneration due to the nearby Leather Industries of Kenya that produced foul odour.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Good	38	76.0	76.0	76.0
	Bad	12	24.0	24.0	100.0
	Total	50	100.0	100.0	

Table 18: Indoor Air Quality Ratings (%)

Respondent however complained on lack of air movement in specific isolated areas of the building, and to fumes from the plumbing system which some occupant felt impacted their health and productivity.

94% of respondents identified natural ventilation as the main means of fresh air provision in the building. Interestingly no respondent identified mechanical ventilation as a means of fresh air provision, with 4% of the respondents not knowing how fresh air is provided for in the building.

Based on the survey results, control of fresh air in the building was mainly through the building operator (56% on average), with occupant control accounting for 44%. No building in the study had incorporated an automated system for controlling air provision in the building. Provision for bettering indoor air quality were provided for in the building with 62% of respondents answering Yes, 10% No with 28% of the respondents not knowing if the building had provisions for bettering air quality.

5.3.6.2 Provision for Bettering Air Quality

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	31	62.0	62.0	62.0
	No	5	10.0	10.0	72.0
	I Don't Know	14	28.0	28.0	100.0
	Total	50	100.0	100.0	

Table 19: Provision for Bettering Air Quality

Access to natural ventilation was identified by respondents as the main mechanism for air quality improvement in the building (64% on average) with ventilation and air conditioning as the other mechanism for air quality improvement. No respondent identified high efficiency air filters or designated smoking areas as mechanisms for bettering air quality in the building.

Sample comments during face to face interviews included:

There are normally issues with the sewer smell emanating from the sump in the basement that permeates the whole building it affects people in different ways: eye irritation, headaches, nausea, breathing difficulties.

Lack of fresh air ventilation system in the building though there is frequent use of operable windows

6 CHAPTER SIX: FINDINGS AND RECOMMENDATION

6.1 Conclusions

Buildings in the area of study incorporated no form of green building design but some had installed some green features such as automatic light sensors. Most of the material used in construction of these buildings was stone and plaster for the walling and iron sheets for roofing. Building orientation to ensure maximum light entry into the building was almost absent in the construction site.

Sustainable building technologies such as incorporating automated system for Heat, Ventilation and Air Conditioning (HVAC) was done by few respondents. Installation of low energy light bulbs and the installation of solar hot-water system and solar panel was among the sustainable building technologies in the buildings. However Lighting quality and air quality were the best rated indoor environmental variables by occupants, who frequently cited the availability of natural light and fresh air provisions in the building.

Occupant satisfaction with thermal comfort was lower than other variables as temperature and humidity both within the range of standards Noise was the most significant area of concern in the building with occupants highly dissatisfied overall, and ambient noise levels found to be within the average to above average range levels. Personal controls were generally frequently used where provided, with the exception of heating controls. Wellbeing was also highly rated, with over three quarters of respondents satisfied with their personal well-being.

Low impact design (LID) techniques was not incorporated into site design in the area of study. These include vegetated conveyance techniques, rain gardens, vegetated roofs and storm water planters and vegetated curb extension which most respondents had no knowledge of or knew their existence. However some respondents had permeable pavements especially those in owner occupied residences.

Challenges most respondents gave for not incorporating green building design and sustainable building technologies were lack of knowledge, expensive green building construction material and lack of skilled manpower to install these features. But the biggest challenge is that Kenya has not promoted the use of these green building features. Most constructors, engineers and developers still ought to use the same old techniques of stone and plaster in developing real estates and buildings.

Thus from the study conducted there were no types of sustainable building designs that existed in the area of study, a rather shocking conclusion opening the doors for further studies on green building design in Kenya.

6.2 Recommendations

Recommendation to promote green building design and sustainable building technologies include the following:

Real estate developers, constructors and engineers should further explore and establish the type of building design and materials that can be termed as "green" instead of using traditional Stone and plaster method.

Sustainable building materials should be exploited and recommended to developers during the planning and construction phase of residential buildings. Home Expo exhibition should try and exhibit some of the available sustainable building technologies and materials in Kenya.

The notion that green is expensive should be discouraged, this study has proved that going green has both financial, social and environmental benefits that in the long run is beneficial to both the occupants and developers.

Local authorities should push planners and real estate developers in their area of jurisdiction to focus on green building designs. Though they have pushed for allocation of solar panels and solar water heaters in building plans a lot remains to be done towards achieving sustainable building technologies.

Other recommendations to promote and provide high levels of occupant comfort and include the following:

• Noise issues may be addressed by installing acoustic panels, carpet (in select areas), and sound-absorbing material finishes on office furniture and partitions. White noise generators may also be considered to increase the level of background noise. .

• Outstanding air quality/odour issues related to the plumbing system need to be resolved, as they continue to be raised by occupants as problematic and posing a concern to health and safety.

• Lack of ventilation systems especially in multistory buildings should be addressed.

• Glare issues form excessive day lighting exposure may be addressed by reducing the source of glare (tin roof and walls), and ensuring that when interior blinds are used to cut out glare, occupants have adequate means of illuminating their homes.

• Lighting control issues could be address by changing the overhead lighting system default from on to off to reduce the number of hours lights are on during daylight hours.

When all these recommendations are addressed and explored further then the challenges faced in implementing green building design both in the area of study and Kenya will be overcome and we will join the major frontiers and countries promoting Green Building Designs that are environmentally sustainable for both our wellbeing and sustainable development.

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APPENDIXES

APPENDIX 1

KENYATTA UNIVERISTY

Department of Environmental Planning and Management

HOUSE HOLD INTERVIEW QUESTIONNAIRE

INTRODUCTION

I am a Kenyatta University undergraduate student pursuing a Bachelor in Environmental Planning and Management. I am carrying out a research on Environmentally Sustainable Building in Residential Building Designs in Makongeni Area, Thika Town, Kiambu County. I am kindly requesting for your time to answer some questions. The information you will provide shall solely be used for academic purpose.

Household Questionnaire

Bio Data Information

Date of survey ____

Name of the interviewer ____

Respondent(s) Name ____

A. Household type (*select only one*)

1.[__] Male headed and managed

2.[__] Male headed, female managed (wife makes most household/ agricultural decisions)

3.[__] Female headed and managed

4.[__] Child headed (below 18 years) / Orphan

B. Type of tenancy

1.[__] Rental 2.[__] Owner Occupied

C. Building overall standard

Would you consider this building to be a "green building"?

1.[__] Yes 2. [__] No 3. [__] I don't know

All things considered, how would you rate the building overall design?

1.[__] Unsatisfactory 2. [__] Fair 3. [__] Satisfactory

In the building as a whole, do the facilities meet your needs?

13.[__] Yes 2. [__] No

D. Energy Efficiency

How well do you think this building is performing in terms of energy efficiency?

1.[__] Very poorly 2. [__] Fair 3. [__] Very well 4. [__] Don't know

Energy consumption per month

1.[__] 0-200 Kshs2. [__] 201-500 Kshs3. [__] 501-1000 Kshs4. [__] 1001-2000 Kshs

5.[__] Over2000 Kshs

How is heating provided in your place of residence?

1.[__]Mechanical system (e.g. forced air, radiator system)

2.[__]Electrical system (e.g. baseboard heaters)

3.[__]Natural passive system (e.g. passive solar)

4.[__]I don’t know

Who is responsible for controlling heating in your place of residence?

1.[__]Automated system (sensor activated)

2.[__]Building operator/caretaker

3.[__]Occupants

4.[__]I don’t know

How is cooling provided in your place of residency?

1.[__]Mechanical system (e.g. air conditioning)

2.[__]Natural/passive system (e.g. slab cooling, shading)

3.[__]I don’t know

Who is responsible for controlling Cooling in your place of residence?

1.[__]Automated system (sensor activated)

2.[__]Building operator/caretaker

3.[__]Occupants

4.[__]I don’t know

Does the building design include provision for Heating, Ventilation and/or Air Conditioning

Equipment efficiency upgrades?

1.[__] Yes 2. [__] No 3. [__] N/A

How would you describe the amount of Day lighting duration? (Amount of Sunlight Entering the House)

1.[__] Adequate 2. [__] Excess 3. [__] Limited 4. [__] No sunlight exposure

Natural light:

1.[__] Adequate 2. [__] Too much 3. [__] Limited 4. [__] Too little

Artificial light:

1.[__] Adequate 2. [__] Too much 3. [__] Limited 4. [__] Too little

How much control do you personally have over the following aspects of your working environment? (Tick appropriately in the table on a scale of 1(no control) to 5(full control))

	1	**2**	**3**	**4**	**5**
Heating					
Cooling					
Ventilation					
Lighting					

How often do you take an action that influences… (Tick appropriately in the table)

	Never(1)	**Once/month(2)**	**Once/week(3)**	**Several times/week(4)**	**Once/day(5)**
Heating					
Cooling					
Ventilation					
Lighting					

Have you employed any of the following measures to reduce your energy bill for the entire building?

1.[__]Installed a solar hot-water system

2.[__]Installed a more efficient heating system

3.[__]Bought low energy light bulbs

4.[__]Fitted wall or floor insulation

5.[__]Turn off lights, appliances not in use

6.[__]Others (please specify) ____

Does the building utilize or make allowances for renewable energy technologies?

1.[__] Yes 2. [__] No 3. [__] I don't Know

Does the tenant/occupant utilize Energy Star rated appliances and equipment?

1.[__] Yes 2. [__] No 3. [__] I don't know

Does the Building utilize high efficiency light fixtures and/or energy efficient lighting controls such as occupancy sensors as well as daylight sensors?

1.[__] Yes 2. [__] No 3. [__] I don't know

E. Site design

Does the site design incorporate tree preservation or enhancement in order to provide urban habitat for wildlife, provide cooling effect for pavement and rooftops, reduce storm water runoff and provide for cleaner air?

1.[__] Yes 2. [__] No 3. [__] N/A

Are low impact design (LID) techniques incorporated into the site design (to provide for storm water infiltration and evapo-transpiration)?

1.[__] Yes [__] No [__] N/A (**if yes please tick appropriately)**

2.[__]vegetated conveyance techniques,

3.[__]rain gardens,

4.[__]permeable pavements,

5.[__]vegetated ("green") roof,

6.[__]storm water planters, or vegetated curb extensions

Does the Building utilize methods to minimize the heat island effect generated from rooftops, parking areas, streets and driveways?

1.[__] Yes 2. [__] No 3. [__] N/A

Does the Building provide smart transportation options, including access to public transit, along with bicycle racks, signage and storage facilities?

1.[__] Yes 2. [__] No 3. [__] N/A

F. Material resources

Does the building provide easily accessible dedicated area or areas for the collection and storage of materials for recycling for the entire building? (Material include: paper, corrugated cardboard, glass, plastic and metals)

1.[__] Yes 2. [__] No 3. [__] I don't know

If trash is removed by a private hauler, does the building owner or tenant have a contract in place for recycling collection?

1.[__] Yes 2. [__] No 3. [__] I don't know

Does the building promote the use of environmentally responsible materials? (Recycled materials)

1.[__] Yes 2. [__] No 3. [__] I don't know

Which of the following building product(s) that contain(s) recycled contents or recyclable is/are available in the building design? (Please tick in the box as appropriate)

1.[__]Concrete

2.[__]Brick (or Masonry)

3.[__]Steel

4.[__]Boards or partitions

5.[__]Flooring

G. Water efficiency

Water Consumption per month

1.[__] 0-20 liters 2.[__] 21-40 liters 3.[__] 41-60 liters 4.[__] 61-80 liters 5.[__] Over 80 liters

Is the use of high efficiency and innovative plumbing fixtures and fittings, such as WaterSense labeled, modern toilets, utilized to reduce water consumption?

1.[__] Yes 2. [__] No 3. [__] N/A 4. [__] I don't know

Does the Building utilize individual metering in multifamily units to reduce water consumption?

1.[__] Yes 2. [__] No 3. [__] N/A 4. [__] I don't know

Is the use of rainwater harvesting systems utilized for outdoor irrigation or indoor use to reduce unnecessary use of potable water?

1.[__] Yes 2. [__] No 3. [__] N/A 4. [__] I don't know

Does the landscaping use native plants that will reduce the use of water for landscape maintenance? (Plants that require low water consumption/watering)

1.[__] Yes 2. [__] No 3. [__] N/A 4. [__] I don't know

Are innovative waste water technologies i.e. waste water treatment plant incorporated into the building to reduce generation of waste water and potable water demand?

1.[__] Yes 2. [__] No 3. [__] N/A 4. [__] I don't know

H. Indoor Air Quality

How would you rate indoor air quality?

1.[__]Good 2.[__] Bad

How is fresh air provided in your place of residence?

1.[__]Mechanical ventilation

2.[__]Natural ventilation

3.[__]I don't know

Who is responsible for controlling fresh air in your place of residence?

1.[__]Automated system (sensor activated)

2.[__]Building operator/caretaker

3.[__]Occupants

4.[__]I don't know

Does the building have provisions for bettering the Indoor Air Quality?

1.[__] Yes 2. [__] No 3. [__] N/A 4. [__] I don't know

(If yes, tick as appropriate)

1.[__]Ventilation and air conditioning2.[__] High efficiency air filters 3.[__] Access to natural ventilation4.[__] Designated smoking areas

Does the building design utilize low-emitting materials (low or zero VOC)? (Paints, cleaning supplies, pesticides, building materials and furnishings)

1.[__] Yes 2. [__] No 3. [__] N/A 4. [__] I don't know

How would you describe your overall sense of wellbeing at place of residence?

1.[__]Very poor2.[__] Fair 3.[__] Very good4.[__] Don't know

How would you describe your overall stress at place of residence?

1.[__]Very stressful2.[__] Can cope 3.[__] Not stressful at all