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GREEN BUILDING TECHNOLOGY AND ENERGY EFFICIENCY: THE CASE OF HIGH-RISE BUILDINGS IN KARURA AREA IN WESTLANDS CONSTITUENCY, NAIROBI COUNTY, KENYA.

VALENTINE WENDY A. OWUOR

REG NO.1028923

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DECLARATION

This research proposal is my original work. It has not been presented in any other University or institution of higher learning for any academic credit. All work sourced from other scholars and sources have been duly cited and acknowledged in this document.

Name: Valentine W.A. Owuor **Reg. No.1028923**

Signature …… Date ……

RECOMMENDATION BY THE SUPERVISORS

This research proposal is submitted for examination with our approval as the duly appointed supervisors.

Dr. Asatsa Stephen 1st Supervisor

Signature: ……..……. Date …….

Dr. Evans Wabwire 2nd Supervisor

Signature: ……..……. Date …….

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DEDICATION

I dedicate this project to individuals who continue to inspire me throughout my career growth. First and foremost, to my parents who have played critical role in my pursuit for education up to this level. Secondly, to my husband and child for their endless support through my studies and project work.

ACRONYM / ABBREVIATIONS

AMCEN	-	African Ministerial Conference on Environment
EPA	-	Environmental Protection Agency
GDC	-	Geothermal Development Company
IRENA	-	International Renewable Energy Agency
IPCC	-	Intergovernmental Panel on Climate Change
KNBS	-	Kenya National Bureau of Statistics
KPLC	-	Kenya Power and Lighting Company
NEPAD	-	New Partnership for Africa's Development
SDGs	-	Sustainable Development Goals
UNCED		-United Nations Conference on Environment and Development
UNFCCC	-	United Nations Framework Convention on Climate Change
World GBC	-	World Green Building Council

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ABSTRACT

Construction industry is not only a leading consumer of energy for lighting, cooling and other purposes but also ranks among the largest sources of toxic gas emissions. This has raised the demand for energy efficient building with low utility bills, healthy indoor environmental quality, and minimal ecological footprints. So far, an increasing number of experts, policymakers, governments and multinational agencies led by the UN are advocating for adoption of green building technology. However, the shift to the environmentally-friendly building practices is relatively slower in Kenya as compared to other nations across the globe. This study, therefore, focussed on the adoption of green building technology (GBT) in one of Kenya's high-end markets, Karura, Westlands Constituency, in Nairobi. The project's main objective was to establish the correlation between GBT adoption and energy efficiency of the high-rise buildings in the area between 2013 and 2018. The specific goals of the study were to determine the factors affecting the adoption of the technologies, as well as, the challenges and strategies for addressing the obstacles to embracing GBT in the pursuit of socioeconomic benefits associated with energy efficient high-rise buildings. The project adopted descriptive research design model. Digital and printed questionnaires were used to collect data from 350 out of the 4,392 industry stakeholders including surveyors, architects, house owners, engineers and real estate agents. Their input was analysed using SPSS. It was found that more than 298 of the respondents used various types of green building innovations such as eco-friendly materials, smart HVAC systems and renewable energy to improve the energy efficiency of their latest projects. While the factors affecting the adoption of the sustainable development concepts included costs savings associated with green building technology, level of awareness and lack of adequate support by the relevant governmental agencies. Consequently, the study recommends dissemination of information to the stakeholders via various awareness programs such as regular conferences, webinars, training programs, and trade shows and exhibitions. The policymakers should also move with speed in providing subsidies and related legal framework to hasten the shift to the green building innovations.

OPERATIONAL DEFINITION OF TERMS

Energy Consumption:	refers to the total amount of energy consumed by occupants of a building for various purposes such as cooking, heating, lighting and others (Banerjee et al., 2017)
Energy Efficiency:	buildings and equipment designed to use the least possible energy thereby minimizing their ecological footprints (Muiruri, 2018).
Environment Quality:	refers to the level of toxic and harmful substances on the environment. E.g. healthy indoor air quality contains negligible amounts of carbon and other emissions (Saka & Chan, 2019)
Green Architecture:	collection of buildings, roads, bridges and other physical infrastructures constructed using GBT so as to minimize their energy consumption and promote environmental friendly practices.
Green Building:	are the building designed to minimize the negative impacts on the environment throughout their lifecycle from the landscaping to demolition phases (UNEP, 2020)

Green Growth:	is the increased adoption of environmentally friendly building concepts and related technologies in line with SDGs.
High Rise Buildings:	are multi-story buildings with heights above 50 metres hence require mechanical vertical transportation system.
Renewable Energy:	is the energy that comes from resources whose regeneration rate is faster than extraction rate.
Water Efficiency:	refers to the action of reducing water wastage by determining the amount of water consumed by a household and implementing strategies to ensure use of the least possible amount (UNEP, 2020).

CHAPTER ONE

INTRODUCTION

1.0 Introduction

This introductory chapter provides background information on the relationship between green building technologies and energy efficiency of the high-rise building. The section also describes the research problem that necessitated the study. It further defines the objective of the project, research questions significance to various stakeholders, theoretical framework and scope of the study.

1.1 Background of the Study

The global demand for energy in all the economic sectors especially construction industry has been rising at an alarming rate (Macmillan & Turrentine, 2021). In fact, the exploration, production and consumption of energy by the worldwide construction sector is a leading generator of greenhouse gas emissions. The households' utilization of energy for various purposes including cooking, heating, cooling, ironing, lighting, entertainment and others, therefore, remains a leading barrier to achieving sustainable development goals (SDGs). According to (UNEP, 2020), buildings use over 38% of energy in supply and emit about 34% of the greenhouse gases. In the United States alone, more than 76% of the electricity generated and over 40% of the carbon emissions are from residential, commercial and industrial buildings for cooling and lighting purposes (EIA Report, 2015).

However, the high energy consumption poses severe economic, social, environmental and health risks. The statistics by the European Environment Agency (2017) indicates that adverse impacts of the unsustainable consumption of energy is distorting the ecosystem through dangers such as global warming. The world is in serious need for energy efficient infrastructures alongside other strategies for addressing the global energy crisis. Therefore, the environmentalists, policy makers, architects, scholars and other experts are advocating for the

deployment of the green building technology/GBT (Iqbal, 2021). There is consensus that the rapid deployment of the eco-friendly technologies would be key to accomplishment of multiple SDGs including combating climate change, zero net emissions, minimal utility bills, increased access to high quality housing facilities and others (Kapoor et al., 2019; Sangori et al., 2020).

GBT has several aspects but use of renewable production inputs is essential in the green certified buildings (Chen et al., 2021). The environmentally friendly energy sources are further boosted with green innovations such as smart heating, ventilation and air conditioning (HVAC) equipment that harness natural light to minimize use of energy and improve the quality of indoor environment. Moreover, GBT entails procurement of energy-efficient construction materials in ways that minimize waste, and create healthy and productive environments. In other words, GBT involves establishment of green housing facilities and related infrastructures by leveraging sustainable processes, as well as, eco-friendly inputs throughout a building's life-cycle (Act, 2017). GBT begins at the design stage and apply in all the phases including construction, maintenance, renovation and even demolition. Consistency in application of the technology results into high-performance building.

The energy efficient buildings lead to low prevalence of health conditions associated with the conventional housing facilities. According to the World Health Organization (2019), the respiratory disorders resulting from poor indoor environment quality ranks among the top five causes of death. However, features of the high-performance buildings such as free flow of natural air and reduced carbon emissions are eliminating such threats. At the same time, the renewable energy is relatively cheaper than the fossil substitutes. Studies have showed that home solar systems are significantly cheaper than comparable fossil fuel (Kuik et al., 2019; Wagner et al., 2021; Klemke-Pitek & Majchrzak, 2022).

So far, GBT adoption rates varies with the advanced economies boasting of the widespread of the associated benefits. For example, European countries lead in investments in ambitious renewable energy projects such as wind, solar, hydro, tidal, geo-thermal and biomass (European Union, 2018). The United Kingdom particularly has shown remarkable commitment in encouraging sustainable development in the building sector (Wang, 2015). Recently, twenty-three of the United Kingdom's most influential construction operations supported the new energy bill by signing an open letter by Chancellor of the Exchequer seeking to provide the foundation for economic growth and reliable production of affordable energy that is restorative and regenerative by design (United Kingdom Green Building Council, 2019). This shows that the UK private sector is also at the forefront in converting the potential of GBT into real values for the stakeholders. Such industry players urged the government to use the proposed Environment Bill to set legally binding energy conservation targets such as minimization of biodiversity loss, improving water and air quality and cutting down natural resource use and waste. The incentives are expected to enable Britain to become a low carbon economy (EU SME Centre, 2013).

On the other hand, access to energy-efficient buildings remains low across the African Continent. According to Okintande et al. (2020), Africa accounts for about 3 per cent of world energy consumption, the lowest per capita modern energy consumption in the world. Even the fastest growing economies in the region are yet to address the energy problem. For example, Tunisia has been battling for energy efficiency for the past thirty (Econostrum, 2017). Tunisia was ranked 18th out of 111 countries for energy efficiency by the World Bank (Banerjee et al., (2017). Despite setting ambitious carbon emission reduction target of 41% over 2010 figures by the year 2030, sluggishness in shifting to GBT and related energy efficient technologies may undermine the accomplishment of the SDG.

Nigeria has also been keen on going Green. However, rapid urbanization has been subjecting the West African nations to the sprouting of substandard housing facilities with high carbon footprints (Ekong, 2017). Nigeria is also vulnerable to storms due to its long coastline, over 800km in length, making the energy and other physical infrastructure susceptible to regular disruption (Ayodele, 2015). This means that shifting to self-sustaining affordable housing projects that uses renewable energy sources would go a long way in solving the housing problem in the country.

Locally, as much as Kenyan government continues to launch new reforms to increase the supply of green building, few buildings are energy efficient (Sangori et al., 2020). The largest portion of building construction projects is taking place in Nairobi. The city has over 4 million residents and the populations is growing by about 4% annually. However, majority of the Kenyan construction industry practitioners and developers are yet to adopt green construction despite the numerous advantages as would have been expected **(**Yin, 2017**).** A survey by Kenya Property Developers Association/KPDA (2018), indicates that the housing deficit exceeded 2 million with over 61% of the urban dwellers living in the slums. The former government through its big 4 agenda sought to construct affordable houses.

The private developers are also launching new projects yet few industry players are likely to achieve the desired energy efficiency and green features (KPDA, 2018). However, construction of a single high-rise building using the conventional methods can cause irreparable damage not only to the surrounding environments but also to the future occupants. As Cheela et al. (2021) explain, the long-storied buildings can increase the temperature of a microclimate by between 1and 7^0 Fahreniheit through the urban heat islands effect. The voluminous amounts of construction materials including steel, sand, cement, wood, water are threats to environmental degradation and massive emission of toxic gases (Luhar & Luhar, 2019). Therefore, the country should move with speed in launching reforms to support the shift

to green building technologies. Wagner et al. (2021) found that use of off-grid solar home systems in Kenya reduced the households' monthly expenditure on energy by Ksh.193. Other economic benefits include employment creation. The increased research and development on GBT create demand for technology-savvy architects, surveyors, engineers, contractors, masons, warehouse managers and many others. Knowledge in international standards, metrics or models used in GBT projects increases access to lucrative opportunities. These include Building Research Establishment's Environmental Assessment Method (BREEAM), Leadership in Energy and Environmental Design (LEEDs) and others (Kamionka, 2017).

Currently, Nairobi is reporting emergence of green buildings with high end markets accounting for the largest share of such high- performance buildings. Good examples include UNEP Building, 3408 Belva Apartments in Parklands, CUEA learning Resource Centre. According to Kenya Green Building Society/KGBS (2022), there only 89 green certified buildings, however, the country has millions of housing units. Consequently, the project sought to determine the effects of adopting of GBT in overcoming the high energy consumption among the high-rise buildings. The study concentrated on Karura area in Westlands constituency due to the region's geographic advantage such as high concentration of the wealthy real estate investors.

1.2 Statement of the Problem

The continued application of conventional building methods lowers the chances of meeting the needs of both the current and future stakeholders. The demand for energy particularly among the occupants of high-rise buildings are rising beyond the sustainable levels**.** According to de Oliveira Neves & Marques (2017), the construction supplies such as aluminium, cement, steel and concrete embodied energy content. The manufacture of HVAC systems also emit toxic compounds such as halons and chlorofluorocarbons. Other studies have also showed that high

rise buildings often create urban heat island where the heavyweight materials store heat during the day and release back to the environment (Mirrahimi et al., 2016; Nugroho et al., 2022). Similarly, skyscrapers often lead to heat urban island, and high demand for oxidation ponds for sewage treatment (Al-Kodmany, 2022).

The mismatch between demand and supply of affordable housing exacerbate the energy crisis that has so far caused persistent rises in prices of electricity and cooking gas. KPDA (2018) found that the demand for housing units exceeds 2 million while only 50,000 are constructed annually. The prices for the housing facilities with energy efficient are significantly higher than the conventional ones. Russo (2022) report that the supply of quality houses is hampered by limited flow of financial incentives, persistence rise in construction costs and low purchasing power of the consumers across the demand value chain. The need of using green innovations in the construction industry thus has become prerequisite for fostering socioeconomic prosperity in terms of lowering households' utility bills and access to comfortable and healthy air quality.

Moreover, GBT adoption rate so far cannot adequately satisfy the consumers' needs. Many people relocate from the Central Business District (CBD) to escape from the congested spaces only to rent overpriced offices and commercial houses with high energy and water consumption. For example, Westlands has experienced increased business nodes due to the relocations (KNBS, 2019). However, the leasing costs are relatively higher in Westlands as compared to other parts of the city.

Besides the concern over the leasing costs, Westlands has a legacy of being pace setter in environmental conservation. That is, the Nobel Peace Prize winner, Wangari Maathai, founder of Green Belt Movement also established a large-scale conservation forest in Karura area. The

construction practitioners in the area, therefore, have a responsibility of enhancing their clients' access to the industry's best products and services.

However, knowledge gap exists on the real experiences of the construction practitioners while undertaking the green projects. Kimani and Kiaritha (2019) studied the social economic benefits of green buildings of the tertiary institutions in Kenya. On the other hand, the institutions are better off in tapping into the benefits of GBT than the private developers based on their strong financial background. Mulei (2021) also conducted case studies of effects of energy efficiency on indoor air quality of four buildings in Nairobi. The study does not provide comprehensive view of the state of GBT adoption rate and factors affecting the deployment of the technologies by the stakeholders. Oduho et al. (2022) conducted a survey on the green building users' awareness and perceptions towards the green building concepts. In contrast, the growth of GBT depend on several other factors such as costs of the technology and existence of supportive policies. This project presented the professionals with opportunities for addressing the factors affecting the application of GBT in delivering high performance buildings to their clients.

1.3 Research Objectives

The project's primary objective was to examine the deployment rate of GBT in constructing energy efficient high-rise buildings in Karura area in Westlands Constituency, Nairobi County between 2013 and 2018.

1.3.1 Specific Objectives

The study aimed at fulfilling the following objectives

i. To determine the adoption rate of green building technologies among the energy efficient high-rise buildings in Karura between 2013 and 2018

ii. To find out the factors influencing the deployment of green building technologies in constructing energy efficient high-rise buildings in Karura area

iii. To examine the challenges undermining the use of green building technologies in constructing energy efficient high-rise buildings in Karura area.

iv. To establish the intervention strategies needed to enhance the diffusion of green building technologies in constructing energy efficient high-rise buildings in Karura area.

1.3.2 Research Questions

i. What proportion of the stakeholders of high-rise buildings in Karura area, have improved the energy efficiency of their projects by adopting appropriate green building technologies?

ii. Which factors necessitated the shift to the green building technologies or energy efficient high-rise buildings in Karura area?

iii. What challenges did these stakeholders face in adopting the green building technologies?

iv. Which intervention strategies can the stakeholders implement to ensure consistent and steady diffusion of the energy efficient and related green building technologies in Karura area?

1.4 Research Assumptions

The study was conducted under the following assumptions:

i. A significant proportion of the buildings in Karura are high rise

ii. The concept of GBT is known and is improving the energy efficiency of the high-rise buildings in the area

iii. The various service providers and professionals in the building industry are familiar with the green building technologies

iv. The government and local licensing authorities support the adoption of GBT and the quest to increase energy efficient buildings throughout the area

v. The challenges encountered in the shift to GBT are preventable through appropriate intervention strategies

1.5 Justification of the Study

This research aimed at providing insights into the changes needed to speed up the deployment rates of green building technologies establishment in Kenya. However, Literature indicates that most of the green building technologies used in Africa are still under testing hence are subject to future improvements (Saka & Chan, 2019). There are also concern that the GBT developed in the western countries often results into low productivity until they are significantly customized based on the local environmental factors (Zheng & Lin, 2017). Therefore, focusing on the deployment rates in Westlands Karura construction industry require timely and unlimited access to vast information so as to achieve the desired performance levels. This study involved the evaluation of energy consumption in green buildings in Kenya with an aim of enhancing the diffusion of mutually benefitting energy efficient technologies to the home owners, construction professionals and the consumers.

The project sought to establish the economic challenge undermining the uptake of green building technology in Karura area. It also encourages the building owners to work hand in hand with government in developing the proactive measures for preventing the risks undermining the growth of the countrywide construction industry. The procedures, methodology and outcomes of the study resulted into new insights thereby enhancing the growth of green buildings theory and practice. Moreover, the study provides useful insights on the energy consumption patterns by the high-rise buildings. As a results, the outcome will inform policy decisions and adjustment of building designs. The stakeholders will gain first-hand information on the industry best practices for maximizing values from the energy efficient

technologies. Furthermore, future researchers will benefit from the primary data relating to the spread of GBT in Karura area, as well as, the strategies needed to enhance increased investments in various segments of the sector including supply of eco-friendly construction materials and engineering firms. Such knowledge growth presents valuable inputs into the scholarly debate on the effectiveness of green building technology on the growth of the contemporary construction industry.

1.6 Significance of the Study

The study will contribute valuable knowledge to the green building concept, as well as, the measures for mitigating the effects of energy crisis by conserving nature. The study will impact positively on the construction practitioners, landlords, researchers, policymakers, and the consumers. By examining the adoption rate trends and factors hindering the shift to the GBT, the study yields new information that will enable the construction firms to pursue the emerging opportunities. With the knowledge, the developers, designers, contractors, and suppliers are better positioned to navigate the challenges hindering the steady adoption of the technology. At the same time, the primary data gathered and suggestions for future research provide the scholars with significant insights into the sustainable approaches for increasing the supply of energy efficient buildings.

The policymakers also learn about the new opportunities for collaborating with other stakeholders in establishing regulations for promoting the adoption of GBT not only in Karura area but across the country. The data collection instruments sought for new data for implanting actionable measures for accelerating the use of green building technologies in the study area. Therefore, the outcomes will go a long way in arriving at sustainable solutions to the currents barriers to switching to energy efficient housing facilities.

1.7 Scope and Delimitation of the Study

This study concentrated on all high-rise buildings constructed between 2013 and 2018 in Karura area in Westlands Constituency. These included all the tall/storeyed buildings exceeding 50 metres that were launched in 2013 and completed by 2018. The data used was collected by surveying the stakeholders that participated in the designing, constructing and managing of such buildings (Lewis, 2015). Online questionnaires were employed to obtain opinion from the respondents who comprised architects, quantity surveyors, property managers/owners, building contractors and engineers.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter review the work done by other researchers including the theories and empirical findings associating GBT and the spread of energy efficient high-rise buildings. The chapter begins with brief discussions of relevant theories that guided the analysis of the survey findings. Thereafter, it conducts a review of empirical studies and summarizes the research gaps in the study area.

2.1 Theoretical Framework

2.1.1 Diffusion of Innovation Theory (DIT)

E.M. Rogers developed DIT in 1962 (Shibeika & Harty, 2015) to explain the spread of disruptive or innovative product, technology or idea from the inventor to other stakeholders across the industry. The theory describes the flow of new knowhow, disruptive products or services from the inventor to various users from across the globe (Mahajan, 2010). For example, once new GBT emerges the inventor tries out in a few projects and eventually it flows from one market to the next until it reaches all parts of the world.

DIT occurs through five stages. First, in the 'knowledge' phase involves the discovery of new products, novel ways of solving market problems or of delivering commodities to the consumers (Eleftheriadis & Anagnostopoulou, 2015). The stage basically involves emergence of a new innovation. The second stage entails persuading others to try out the discoveries. At this phase, the innovations are still not well-known in the market. At the third phase, the targeted users either adopts or reject the new commodities. While in the fourth and the fifth stage there is continued implementation and confirmation of the innovations (Chang, 2010).

Several earlier studies have employed DIT. In a study by Gholizadeh et al. (2018), DIT was used to determine how embedding information and communication technologies such as Building Information Modelling, 3D visualization and energy modelling not only enhanced the aesthetic features of houses but also their sustainability component. Ezcan et al. (2020) also utilized DIT to study the diffusion of research findings on architecture, engineering and construction. The study also examined why the ICT often fail to reach their potential in the long run leading to low diffusion rates. While Lee & Park's (2022) research on the competitiveness of smart technology in construction industry employed DIT to access the state of GBT since the onset of fourth industrial revolution. Therefore, the studies provide evidence that application of DIT was ideal in full filling this project's objectives.

However, DIT has some weaknesses. For example, although innovations are always subject to obsolescence the late adopters and laggards often embrace them whenever they are no longer considered valuable (Berry & Berry, 2018). At the same time, DIT's application depends on the perception of consumers of the innovative commodities (Ozaki, 2011). While a consumer may consider a GBT launched in early 2000s as effective, others may regard it as an old technology hence would rather adopt the latest trends in the industry. Nevertheless, the difference in people attitudes towards the newly launched building products, construction technology and ways for achieving energy efficiency helps in categorizing the users as innovators, early adopters, early majority, late majority and the laggards (Lee & Park, 2022).

The theory relates to the independent variables. Factors, such as GBT awareness, costs of shifting to the green building concepts and legal frameworks all affects the adoption of the technology and their application in achieving energy efficiency (Gholizadeh et al., 2018). DIT was further employed to gain insights on the consumer behaviours towards new building inventions. It helped to determine whether the respondents were innovators, early adopters or laggards. However, the innovations work best whenever interrelated components of the

systems are well designed to meet the needs of the users. For example, GBT users need training in order to gain relevant skills, acquisition of compatible hardware systems and support from various stakeholders. As George et al. (2019) cite, Kenyan construction firms have often struggled to implement green building technologies that have been successfully launched in other international markets. For example, although Kenya is vibrant solar energy market, the consumers have been complaining of mismatch of transmission infrastructure, high initial cost of equipment. At the same time, as much as a construction firm may successfully install a solar panel, the house may not necessarily become energy efficient until all the other components including floor, HVAC systems, as well as, both internal and exterior décor are designed to achieve zero carbon emissions. Therefore, general systems theory can be applied to understand the specific and holistic interventions measures needed to solve the barriers to effective deployment of various types of GBT in maintaining energy efficient buildings.

2.1.2 General System Theory (GST)

Talcott Parsons and Niklas Luhmann founded GST model in 1935 The theory view phenomenon as a complex system comprising several subsystems. For example, nature comprises society, populations, biodiversity, science, and policy framework (Kibert, 2016). Therefore, access to optimum value only occurs in a society where the players strive to establish seamless interactions among the subsystems. In construction industry, GST regards buildings as an open system comprising interrelated and inter-dependent parts that may include the foundation, pillars, walls, roofs, floors, ventilations, interior decor and others.

GST popularly features in solving multiple problems in the construction world. For example, Kibert (2016) demonstrated that system thinking is effective in increasing the supply of energy efficient buildings as the framework supports planning right from landscaping stage to the end of the construction phases. Similarly, according to Kerzner (2017), GST present the best approach for planning, scheduling, implementation and controlling large scale construction

projects. The theory examines all the stages of project hence increases the success rates and proactive management of risks. Benachio et al. (2020) also showed that GST play critical roles in fostering circular economy in the construction world. The concept users view every aspect of the industry from holistic perspective thereby eliminating threats such as pollution, wastages of scarce environmental resources and improper disposal of wastes.

Overall, GST strengths lies on its approach of examining projects from systematic and holistic point of view. The researchers concur that applying GST in improving the sustainability of buildings ensures that every subsystem of a building will be evaluated on how best it minimises the energy system and contributes to the establishment of high- performance building (Kibert 2016, Kerzner, 2017; Benachio et al. 2020). Therefore, the theory provided comprehensive view of effects of GBT on the energy efficiency of the high-rise buildings. However, the application of GST depends on the skills level of the users. This means that lacking expertise or knowledge in some components of a building may lead to misinterpretation of the impacts of some GBT on the performance level of a housing facility.

In this study, GST connects the independent variables (factors affecting GBT adoption) with dependent variables (overall state of energy consumption among the high-rise buildings in Karura area). The adoption of GBT in high-rise buildings is viewed as a function of several sub-system such as costs, knowledge flow (awareness levels) and existing policy frameworks (Sangori et al., 2020). It is assumed that optimal interactions among these subcomponents lead to rapid growth in deploying GBT in achieving energy efficiency in Karura area and beyond.

2.2. Adoption of Green Building Technologies

GBT is defined differently by various researchers. However, the scholars concur that the term refers to a range of construction techniques for promoting eco-friendliness (energy and water efficiency) of a housing unit or facility, (Alkahtani and Nordin, 2020). The concept emphasizes

sustainable procurement of construction materials, continuous application of various technology to minimize energy and water consumption, as well as, all the scientific processes leveraged to improve quality of air and eliminate threats such as urban heat island and emission of toxic gases (Dedrick, 2010; Hwang & Tan, 2012; Darko et al., 2017; He, 2019).

The invention and flow of GBT is evolutionary. The invention of new techniques often results into greater results, as far as, energy efficiency is concerned. For example, the construction firms are launching new strategies for recycling raw materials, energy and water preservation (Akadiri et al., 2012). For example, it has been found that reusing construction and demolition waste not only saves energy but also prevents carbon emissions by tenfold (Hasham, 2016). Similarly, use of biogas, solar, geothermal and wind energy has long lasting positive effects on environment (Khoshnava et al., 2018). The virtuous cycle resulting from the renewable energy include diversification of energy sources, reduced reliance on imported fossil fuels, clean environments and creation of jobs in the energy production firms.

Other rapidly diffusing GBT include specially designed materials, lighting systems, interior and exterior décor, ventilations and smart devices. Darko et al. (2017) recommend use of building envelopes or thick to reduce air leakage. In contrast, Simpson (2012) advocates for high-performance or large windows and doors, as well as, insulation of the walls, ceilings, and floors. Research shows that the compact fluorescent lamps (CFLs) and light emitting diodes (LEDs) are essential components of energy efficient buildings (Adeleke et al., 2017). Currently, an increasing number of high-rise buildings are using artificial intelligence and other smart technologies to achieve energy efficiency. Thermostat sensors are capable of automatically switching off light whenever rooms are not occupied while AI logarithms are enabling analysis of energy consumption at different times leading to informed decision making (Jia et al., 2019).

At the same time, strategic positioning of the windows towards direct sources of natural light eliminates the demand for energy for lighting systems during the day (He, 2019). Moreover, solar water heating systems are sources for massive energy savings particularly in the multi-story buildings with hundreds of housing units (Doan et al., 2017). The deployment of GBT in high-rise buildings have several advantages over the traditional building. The Conference on Green Building Rating for Africa, indicated that green buildings lead to superior environmental performance (Olawumi et al., 2020). The green building certifications enable the project managers to employ multiple energy conservation techniques resulting into high indoor environmental quality, lower maintenance costs, promotion of biodiversity, and low carbon foot print (Kruger & Seville, 2012; Fan & Xia, 2018; Lee and Park, 2022).

The research, therefore, examined the diffusion rates of the various GBT technologies in Karura area. The data collection questionnaire used in the project ought to determine the extent to which these green building concepts are incorporated into the high-rise buildings. It further determined the benefits of the GBT to the stakeholders.

2.3. Empirical Literature Review

2.3.1 Adoption of Green Building Technology and Energy Efficiency

Several scholars have studied the diffusion of GBT. According to Wuni et al. (2019), the green building innovation has recorded steady growth since 1992. The researchers found that the green building technology movement emerged and took momentum in the 1990s. Its motive then was to promote buildings that are well-designed to reduce energy consumption, use of natural resources and improve human health, as well as, the environmental performance over a long lifecycle. The empirical data collected over the years lays a strong background for the study. For example, the review provides evidence that the influx of GBT has been necessitated by the success rates of recycling and circular economy in lowering the wastage of scarce natural

resources and reduction of greenhouse gas emissions. Similar motives drive the adoption of the technology by the construction practitioners at Karura area. The research adopted a systematic review of 1,114 green building research papers published between the 1990s and 2018. Wuni et al. (2019) found that there has been a tremendous increase in green building research publications which was an indicator of commitment and adoption of the initiative. The review further established that over 195 countries from virtually all the continents had acknowledged green building technology and have strategies for promoting their adoption. Kenya is one of these countries hence the review by Wuni et al. (2019) was helpful in comparing and contrasting GBT adoption rates in Karura and other leading nations such as Netherlands and Australia. The results indicate that the local players as well as the international construction companies are now better poisoned than in the previous years in accessing the various inputs for constructing energy efficient building

A study by Chen et al. (2021), also concentrated on the evolution and spread of GBT across China. The study indicates that china's goal for promoting GBT was to achieve zero emission and promote expansion of green economy over the near future. As a result, the government, China's government launched a mix of legal policies. For example, investing in green buildings attracts subsidy and tax reliefs. The study, therefore, was relevant to examining how the adoption rate of GBT in Karura area depended on the legal factors. Elaborate policy framework must exist in order for the local construction firms to grow at the same pace like in China. The evidence suggest that the firms operating in Karura area are likely to embrace the green technologies at the same or even higher rates than their Chinese counterparts if accorded adequate legal support in terms of monetary and other incentives The findings were in line with an earlier study by Wang et al. (2019). The research aimed at determining the industry best green building technologies by reviewing over 106 different green innovations used in China. The result showed that all the technologies had positive effects on site planning, water-

saving, energy-saving, and indoor environmental quality. However, the lack of comprehensive checklists and high economic cost constrained the applicability of the technologies in the country.

GBT is also steadily gaining roots in Africa. As evident in research conducted by Darko (2019) on the underlying issues influencing the adoption in Ghana. The author acknowledged that GBT is the future of global sustainable development. The study focused on the roles of green building concept in accomplishing sustainable housing development. Darko (2019) surveyed the green building environmental professionals in the country using questionnaire and supplemented the information with comprehensive literature review. The findings revealed that application of HVAC systems, lighting systems, water appliances and fixtures were the most common GBTs used in the country. The study further indicated that research and development, economic support incentives, public awareness programs, awards, information dissemination, introduction of green building standards, and new government regulations have significant influence on GBT adoption in Ghana. As much as the macro-environmental factors characterizing Ghana's construction industry is significantly different from that of Kenya, the research provides useful information on the diffusion of green building concepts. For example, the spread of the technologies discussed by Darko (2019) helped to determine the popular GBT used in Karura area. The study implies that the growth in GBT in Karura area depends on similar internal and external environmental factors. The increased investment in research and development, economic stimulus packages and related support factors results into growth in supply of energy efficient housing infrastructures.

Locally, Mulei (2021) studied two green and non-green buildings in Strathmore and Catholic Universities. The power bills from Kenya Power Company was used to assess the superiority of employing GBT over the conventional building techniques while air quality was measured using metabolic carbon oxide tracer over a four month period. The results showed that

adoption of green building technologies was statistically correlated with energy efficiency and indoor air quality. The green buildings consumed 40% less energy and 0.8 less contaminated air than the traditional buildings. The same benefits were assumed to be major drivers of the increased adoption of GBT in Karura Area. An increasing number of the construction stakeholders are embracing the technology to achieve high performance as measured by energy savings and reduction in toxic gas emission.

Kanda et al. (2023) also studied the adoption rate of green building concept in Kakamega Municipality. 64 respondents participated in the survey including 15 professionals and 49 commercial and residential building owners. 80% of the individuals reported that they had knowledge on water efficiency, energy efficiency, sustainable materials and SDGs. Given that Nairobi's construction industry is more technologically advanced than the rest of the country, the results suggest that more construction practitioners in Karura area should be more knowledgeable on GBT. However, having knowledge on the technology does not necessarily translate into their application in the industry.

2.3.2. Factors influencing the Adoption of GBT

2.3.2.1. GBT Awareness Level

Stakeholders' awareness level on GBT is positively correlated with its application in the construction industry (Samari et al., 2013). Studies have demonstrated that the increased understanding of the green innovations by architects' engineer, investors and real estate agents translate into the influx of green buildings (Wang 2015; Muiruri, 2018; Dadzoe et al., 2021).

Dadzoe et al. (2021) reviewed the roles of green building on accomplishing sustainable development in the Ghanian construction sector. The study adopted a questionnaire as the data collection instrument and construction professionals as the unit of analysis. It aimed at exploring stakeholders' attitudes towards green building technology adoption. Dadzoe et al.

(2021), defined stakeholders' attitude as the emotional experiences, behavioural patterns or cognitive judgments towards green building concepts. It was found that the awareness levels lead to positive-mindedness which, in turn, enhanced the acquisition of GBTs (Dadzoe et al., 2021). The positive attitudes towards GBT's cost-effectiveness, resource efficiency, and environmental friendliness promoted its use by many stakeholders. While the pessimistic stakeholders often overlook the benefits hence continue to use the traditional building technologies. It was assumed that similar observations influenced the adoption rate of the green innovations in Karura Area. For example, those with strong beliefs on the benefits of GBT adopted the technology despite their high initial costs.

However, literature indicates need for increased flow of information on the superiority of GBT over other alternative building technique (Wang, 2015). The publication on the economic, health, environmental, and social benefits has not resulted into the expected increase in popularity of green infrastructures. However, there are strong pieces of evidence that green buildings lead to greater socioeconomic prosperity than the traditional buildings. According to Muiruri (2018), green building designs lowers construction costs by over 13 per cent. While Kapoor (2019), found that adopting GBT always enhances long term returns on investment among the private developers. Such positive publicities are accessible from any parts of the world hence impact on GBT adoption including in Karura area.

Nevertheless, the low awareness on green certifications program, mean that the stakeholders need further training on BREAM, LEED and other models in order to effectively leverage GBT in their projects. Norton & Brayan (2015) found that although the risk adverse house owners' desire to go green, limited knowledge on the options to choose negatively affects their decision-making abilities. Kimani and Kiaritha (2019) also reached similar findings. The study examined the availability of green certification programs in Kenya and their impacts on the green buildings in tertiary institutions in the country. The researchers investigated the

incentives employed by the 141 universities, colleges, polytechnics, and TVET. It was found that the Kenyan firms mostly use LEED and Green Star certifications. However, only 2 buildings out of the houses in 141 institutions of higher learning had attained green certifications due to the low awareness. Consequently, this study also accessed whether the professionals and local authorities in Karura area have taken any necessary actions to clear the knowledge gaps and information silos preventing the stakeholders from making informed decisions.

2.2.2.2. Construction Costs

The cost-benefit analysis of green buildings influences the diffusion rate of GBT. However, most existing study blames the low switch to green technology by high-rise building stakeholders on the high initial costs. For example, Zhao et al. (2015) found that lack of smart devices for monitoring energy consumption patterns has led to the perception that the costs of GBT exceed the benefits. The researchers recruited 115 Chinese respondents who answered questionnaire on their understanding of the green housing facilities and their intentions to purchase them based on humanistic needs such as attitudes and preferences towards economic efficiency and buildings performances throughout their lifecycle. The primary data was supplemented with secondary data gathered via literature review on sustainability trends in China and beyond. Zhao et al. (2015) found that the basic understanding of GBT was still weak and few stakeholders had adequate insights on economic returns on investments from the green buildings. As a result, the consumers rely on basic rating standards to make purchasing decisions which are not always accurate. Similar challenges were expected in Karura area as the influx of relevant technologies such as big data analytics for gaining real time information on energy consumption trends is low. Confusion exists on the acceptable economic models for examining the costs and benefits of adopting particular green building techniques. Therefore, the study projected that availability of databases on such statistics would enable the decision

makers to review the alternative GBTs and adopt those that maximizes value in the long run- in terms of zero carbon emissions, cost savings and profits to be generated by the project management teams.

Another study by Kipngetich (2015) focusing on the global supply chains, showed that the transmission grid bottlenecks pose serious challenges to accessing renewable energy sources needed in the construction and related industries. It was found that inadequate cooperation in the supply chain and limited government support are leading to the reluctance in embracing GBT. For example, the construction material suppliers sell the eco-friendly products at relatively higher prices than the substitutes. Consequently, many construction firms often opt for the affordable options. However, government is yet to implement policies to create a plain or level ground to foster effective competition between green and the rival commodities. The same findings were reached by a study by a systematic literature review by Zhang et al. (2019) comprising data from the official web sites for green building standards in various nations. The researchers reviewed a wide range of academic articles and conference proceedings. The search phrase was green building technology which yielded thousands of articles from diverse fields. According to the study, the challenges facing the green building sub-sector were uncertainty over economic benefits, inadequate policy and support systems, low technology acceptance and lack of comprehensive green certification programs in such regions. All the barriers were incorporated in the conceptual framework in figure 1.1 and the questionnaire. The study, therefore, examined the influence of these impediments on the rate of supply of energy efficient green buildings in Karura Area.

2.2.2.3. GBT Legal Frameworks and Governmental Intervention

Scholars have been examining the availability of relevant laws and national policies for enhancing the use of GBT in constructing energy efficient building. For example, a study by Liu et al. (2019) analysed the role of legal framework in China's progress towards achieving

zero energy buildings. The research explored the features of zero-energy buildings their market share across China and the policy frameworks that supports their adoption in the country. The study found that the rise in such high-performance buildings is attributable to state sponsored research and development, national policies, multi-level codes and standards for energy efficiency and tax reforms (Liu et al., 2019). This study also accessed whether the national and local government has implemented adequate support mechanisms to support construction firms in Karura area.

An earlier study conducted by Kahemba (2013) in Kenya, raised concern over absence of comprehensive green certification framework in the country. The study examined the relevance of LEED and policy frameworks in promoting green building practices in the country. A pilot phase of the study entailed focus group discussions and personal interviews. Questionnaire was used to survey 600 registered construction professionals. Khaemba (2013) observed that lack of adequate regulatory and policy tools alongside awareness interventions was hindering the acquisition of GBT. However, 10 years down the line, all the changes recommended by the study are yet to be implemented. As evident in the study by Mulei (2021), Kenya's policy frameworks lag behind those of the developed countries such as China. The study compared the energy efficiency and indoor air quality of two green and two non-green building in Nairobi. Mulei used GreenMark Standard to compare the energy consumption and other features of the studied buildings. The analysis showed that the green buildings had significantly lower energy consumption and related sustainable features than the non-green houses. The outcome was relevant to this study in two ways. It showed that the current professionals have better green certifications or rating frameworks than in the past. However, the relevant authorities should continue to develop new policies based on the specific challenges faced by stakeholders of Karura area and the country's entire construction industry.

2.3.3. Challenges to Adopting GBT

Studies have identified different challenges to embracing the use of GBT in ensuring energy efficiency. According to Tessema et al. (2010), poor urban planning poses a serious challenge to the sustainable growth of the construction sector. For example, most cities have densely populated high-rise buildings which affect the air movement after construction. The observations were made by Marrakech Task Force which works with several national governments to promote sustainable consumption and production. Tessema et al. (2010) summarized the results into brief book highlighting the state of sustainable construction in Africa. For example, many designers perceive that using multiple eco-gadgets such as solar, wind generators and bio-digesters automatically results into high performance buildings. In other words, it is virtually impossible to attain the desirable energy efficiency of most high-rise buildings without proper planning of the entire construction ecosystem. The construction authorities at Karura area must embrace the sustainable designs to minimize the barriers to desirable performance standards such as urban heat islands.

Research by Hwang & Ng (2013) also showed that conflict of interest among the stakeholders is a major barrier to the steady diffusion of application of GBT in lowering energy consumption in the construction sector. The study was conducted in Singapore where 31 industry experts discussed the various obstacles that slowed down the shift to green building systems. The results indicate that pursuit of personal goals by the key stakeholders have often undermined collective decision making and coordinated investments in energy efficient built infrastructures. For example, while developers want super normal profits, the tenants demand for energy efficient facilities but at the lowest prices possible. As a result, the investors often opt for the conventional buildings (Hwang & Ng, 2013). Similarly, while timber dealers' projects growth in demand due to the expansion of construction industry, the green technology

calls for recycling of the old products. Moreover, retrofitting the energy systems of the old buildings results into non-biodegradable wastes that may cause public nuisance to other people living surround the high-rise buildings (Gottfried, 2016).

Agyekum et al. (2019) also conducted a survey aimed at challenges characterizing Ghana's green building sector. The data was gathered through telephonic and face-to-face interviews. NVivo11 Pro-software were thereafter employed to analyse the data. Agyekum et al. (2019) found that lack of adequate support by the government, the reluctance by the professionals and low awareness levels on the benefits of green building continue to hinder Ghanaians from embracing the disruptive building technologies.

Recently, Addy et al. (2021) did research on the impediments to the growth of green building in sub-Saharan Africa. The building consultants were surveyed using structured questionnaires. Besides the factors that were identified by Agyekum et al. (2019), the study cited inadequate fiscal incentives and educational programs to promote green building concepts. Locally, a study by Kanda et al. (2023) studied the GBT practices in Kakamega Municipality. The project involved 64 respondents with 15 being construction practitioners while 49 were other stakeholders of the sustainable buildings. It was found that 80% of the professionals were informed about water and energy efficiency, as well as, sustainable materials. However, the implementation was significantly lower than the awareness rates. For example, about 42.9% of the studied buildings had bio-retention and permeable movements. This implies that despite the majority of the construction industry professionals being privy to information on GBT only half of them have access to the financial, material and expertise needed to adopt them.

2.3.4. Strategies for Promoting Use of GBT

Scholars have proposed a number of incentives for promoting the green infrastructures. Tran et al. (2020) engaged the Vietnamese construction developers on the approaches for promoting sustainable development of construction industry in the developing economies. The

respondents believe that leadership approaches in terms of implementation of policies, as well as, research and development would go a long way in enhancing the acceptance of GBT in the low-income countries.

The roles of local authorities also featured in a study by Willar et al. (2021). The research focussed on enablers of sustainable development of construction sector in Indonesia. The study participants included the construction practitioners that were involved in road, building, bridge, and water projects in the country. The team recommended that the government through the ministry of housing and public work should update the existing legal frameworks. In contrast, Nižetić et al. (2019), advocated for upgrade of the curriculum to incorporate the emerging green building technologies. The study focused on strategies for promoting smart technology. According Nižetić et al. (2019), continued professional development courses aimed at not only equipping the building professionals with GBT skills but also providing certificates and opportunities to manage the high-profile green projects throughout the world. Moreover, the scholars proposed that the governments should introduce mandatory energy audits. This will require the building owners to acquire energy performance certificates and submit data on their monthly utility consumption to the relevant local authorities.

Study conducted in Kenyan construction industry by Sangori et al. (2020) also supports the implementation of comprehensive legal frameworks. The paper reviewed the on-going policies, regulations and standards for enhancing the use of location specific sustainable building materials. Key informant questionnaire was sent to experts from relevant agencies such as housing development and urban regeneration programs, National Construction Authority, KGBS and others. Findings indicate that although over 20 policies exist on sustainability, 77.4% of the respondents argued that the frameworks need significant improvements so as to promote uptake of emerging technologies, standardization of building materials and develop better financing strategies. Therefore, finding out the perspectives of the

construction practitioners from Karura area was also conducted in this study. The respondents' viewpoints are further present to enable the authorities gain new knowledge on the actionable approaches for speeding up the flow of GBT across the industry.

2.4. Chapter Summary

The study was anchored on DIT and GST theories. DIT emphasizes that the rate of diffusion of new technologies such as GBT occur at different levels among the stakeholders. Innovators and early adopters are often motivated to pursue for novel ideas and thus often finds ways for overcoming the obstacles. The early majority wait until information about the invention has penetrated into the market while the late majority and laggards are always reluctant to acquire new inventions. The school of thought helped to understand the respondents' attitude to GBT. Similarly, GST aspect particularly system thinking provided approach for navigating the various challenges affecting the increased deployment of green building innovations to produce high performance buildings.

The empirical literature indicates that GBT diffusion rate has gained momentum across the globe. That is, almost all countries are increasing their efforts towards greening their construction industry The scholars attribute the growth to the positive impacts of the high-performance buildings such as low utility bills, healthy indoor air and low environment pollution. However, the benefits come at costs like heavy initial capital outlay, low awareness level and insufficient government support. As a result, the strategies point towards introducing financial, legal, research and development support mechanisms.

However, there is knowledge gap in the area. So far, few scholars have provided conceptual understanding and empirical evidence on the spread of green building technology in Kenya and Westlands. On the other hand, most of the existing data on sustainable building approaches were conducted in either developed countries or African countries with different macro-environmental factors from Kenya. Therefore, this study sought to fill the gap by presenting

new data on the extent to which the professionals in Karura area are leveraging the emerging green innovations to establish energy-efficient high-rise buildings.

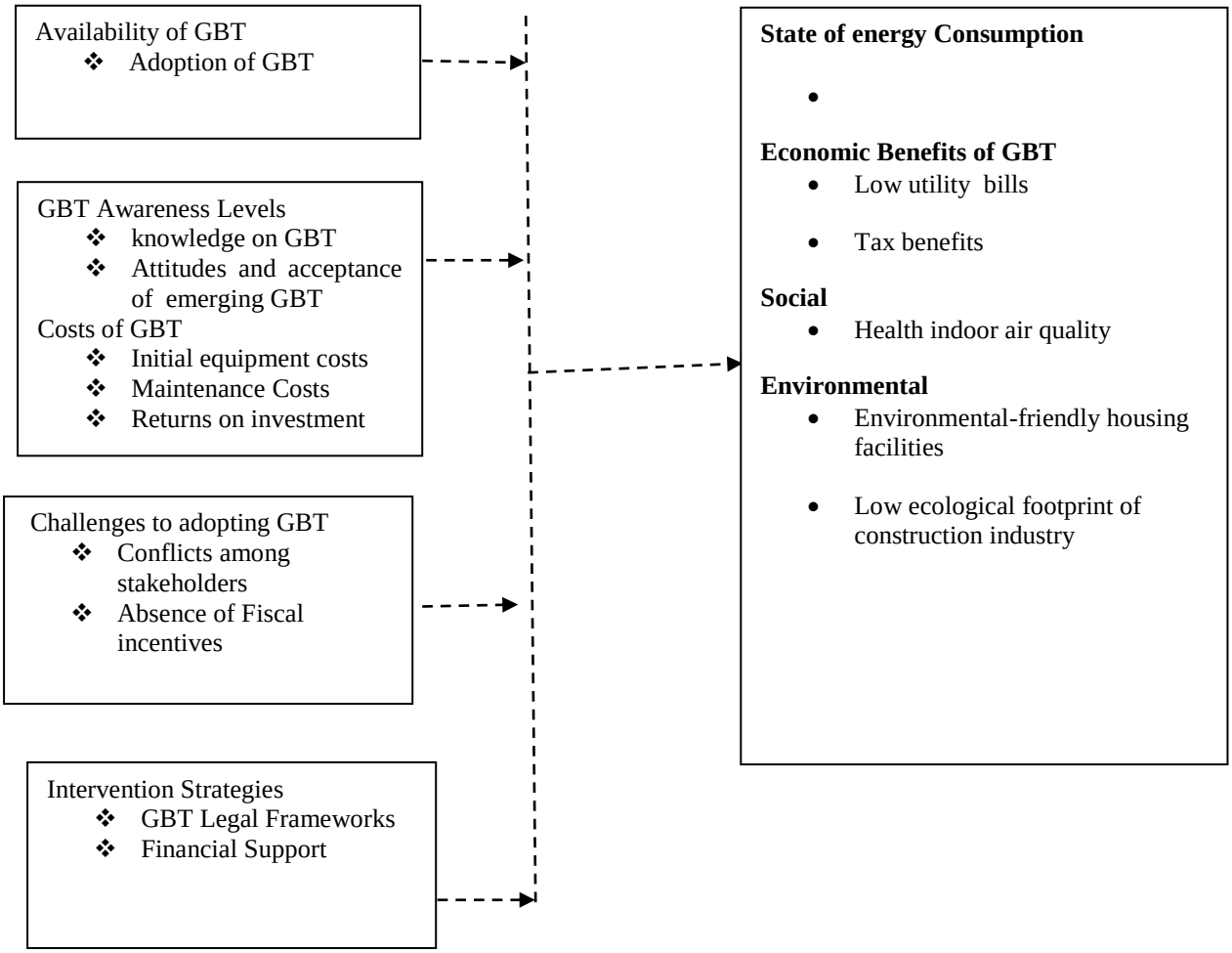
2.5 Conceptual Framework

The conceptual framework was as depicted in figure 2.1. The independent variable included the factors affecting the adoption of energy efficient and green building technologies such as stakeholder awareness on the green building technology, construction costs and support from local authorities. While the dependent variables were overall state of the energy consumption by the high-rise buildings in Karura area as measured by the adoption rate of GBT, reduction in greenhouse gas emissions, growth in environmental conservation as a result of the technologies and the changes in households' expenditures on energy.

Figure 2. 1 Conceptual Framework

Independent Variables **Dependent Variable**

(Factors influencing GBT adoption)



(Source: Author, 2023)

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.0 Introduction

This chapter presents the procedures that was employed in gathering and analysing data for fulfilling the research objectives. It comprises research philosophy, design, target population, sampling techniques, and instruments used to collect data. The section also explains how the collected data was analysed in line with the study objectives.

3.1 Research Paradigm

Constructivism presented opportunity for exploring the relationship between factors affecting deployment of GBT and energy efficiency of the High-rise building in Karura. (Bogna et al., 2020). The research philosophy view reality from the point of view that individual's understanding of a phenomena grows with exposure to new experiences, which in turn, add value to the shared meanings. The knowledge gained through observation, measurement, interviews and survey of the various stakeholders in the construction industry is more trustworthy than the mere beliefs in the effects of green building technology. For example, the architects, real estate managers and engineers are witnessing the positive outcomes of the green innovations on the buildings. Constructivism also allows for collection of holistic information thereby enabling qualitative analysis. As a result, the paradigm helped in critical analysis of the research problem.

3.2. Research Design

The project adopted a descriptive research design. It was ideal for fulfilling this study objective because it presented opportunity for reporting the results, respondents' views and observations without controlling or manipulating any of the variables. According to Siedlecki (2020) descriptive research design is preferred whenever little information is known about the

phenomena. Like in this case, limited knowledge exists on the use of GBT on constructing energy efficient buildings in Karura. Descriptive design, therefore, allowed the researcher to determine how and why the construction stakeholders in the area are embracing the energy efficient technologies (Aggarwal & Ranganathan, 2019).

3.3 Site Description, Study Population and Target Population

3.3.1. Site Description

Westlands is one of the fastest growing constituencies in Nairobi, Kenya located 3 kilometres, North West of Nairobi Central Business District. It covers an area of 72.4 km2. The constituency is unique as compared to other neighbourhoods because it has in it some of the most affluent localities, as well as, some of the poorest (slum) areas in Nairobi County. It comprises of both residential and commercial buildings and attracts financially established persons and expatriates. The location attracts many people due to the well-established malls such as Westgate, Sarit Centre, the Mall and others. Karura is a known affluent neighbourhood and administrative division in Nairobi. It hosts high end shopping malls, offices and entertainment joints (Westlands, 2018). Previously Westlands was mainly a residential area with few shops but has transformed over the recent past to a commercial zone with several offices and shopping centres. As shown in figure 2 below, the constituency has five wards namely Kitisuru, Parklands/Highridge, Karura, Kangemi, and Mountain View.

Figure 3. 2 Map of Westlands Constituency



(Source: Westlands, 2018)

The study will focus in Karura area since it boasts of most the new buildings in the Constituency. However, the target population included the architects, engineers, quantity surveyor, building contractors, property owner/managers from across the region.

3.3.2. Target Population

The target population included the stakeholders in the construction industry within Karura area. Concentration was on the individuals with knowledge and experience on the emerging trends in the high-rise buildings sector particularly the energy efficient technologies and related green innovations (Mugenda & Mugenda, 2013). The table 3.1 below shows the number of the registered construction professionals serving Nairobi Metropolitan Area. The list is derived from the official stakeholder's regulatory bodies, as mandated by the respective Kenyan ACTs.

These regulatory bodies are authorized to train, inspect, register and authorize their members as well as supervise their ethical conducts while practicing in the construction industry.

Table 3. 1 Study Target Population

Respondent (Stakeholders)	Target Population	Source:
Architects	1069	Board of Registration of Architects and Quantity Surveyors (BORAQS) Kenya
Engineers (Structural)	157	Engineering Board of Kenya
Quantity Surveyors	686	Board of Registration of Architects and Quantity Surveyors (BORAQS) Kenya
Contractors	2048	National Contractors Authority (NCA)
Property Managers	432	Estates Agents Registrations Board (EARB)
Total	**4,392**	

(Source: BORAQS, 2021; EARB, 2021; EBK, 2021; NCA, 2021)

All the 4,392 individuals comprised the target population. These professionals have projects all over Nairobi Metropolitan area including Karura or Westlands area. They, therefore, are privy of information on the factors affecting the adoption of GBT across the area

3.4 Sampling Procedures and Sample Size

Stratified and snow-ball sampling techniques were used to select clusters or blocks to be used in the study. The former involved dividing the targeted respondents based on their geographical locations. In this case, the study targeted professionals based in Karura area and its environs. The strata included architects, engineers, quantity surveyors, contractors and property managers. Stratified sampling technique was convenient and eliminated bias as all the registered professionals engaged in various projects within Karura area had equal chances of participating in the study. While snowball sampling criteria helped to recruit the participants with first-hand information on the state of energy efficient and GBT in the area. The researcher first read business magazines and reports by various real estate analysts such as Kagai (2017)

and Cytonn (2022) to familiarize with the major green building projects in the area. The first responded included the lead architects, engineers, surveyors, contractors and owners of the green buildings in the area. The researcher further visited Karura area to recruit the targeted respondents who helped in accessing other individuals with the needed information (those who were involved in constructing high-rise buildings in Karura area between 2013 and 2018) until the desired sample size was achieved. The sample size was based on the recommendation by Mugenda and Mugenda (2013) that 10% to 15% of the total population of the subjects for any descriptive study is acceptable. In this case, 10% of the respondents were chosen per strata. Therefore, the sample size per strata was as shown in table 3.2.

Table 3. 2 ***Targeted Respondents per Strata***

Respondent (Stakeholders)	Target Population	Sample size (10% of Target Population)
Architects	1069	107
Engineers (Structural)	157	16
Quantity Surveyors	686	67
Contractors	2048	205
Property Managers/Building owners	432	43
Total	**4,392**	**440**

(Source: Researcher, 2023)

The researcher further used the Yamane (1967) formula to calculate the number of respondents who took part in the survey as indicated below:

$n=N/(1+N(e)^2)$ where;

n: is the sample size

N: is the target population

e: this is the margin of error (0.05)

Thus the the sample size was

$n= 4,392 / (1 + 4,392(0.05)^2)$

$n=4,392 / (1+ (4,392 \times 0.0025))$

$n=4,392 / 11.98$

n=367 respondents

Thus, the sample size population used was 367 respondents which were further distributed amongst the stakeholder categories using the formula: (Sample size / total sample size) x total sample size of respondents = sample size in each category as depicted in table 3.3 below.

Table 3. 3 Sample Size

Category	Stakeholder sample	Sample size in each
Architects	107	89
Engineers (Structural)	16	13
Quantity Surveyors	67	56
Contractors	205	170
Property Managers/ Building owners	43	39
Total	**440**	**367**

(Source: Researcher, 2023)

3.5. Data Collection Instruments

Data was obtained via questionnaires the respondents had the options of choosing printed questionnaires or digital questionnaire forms that were distributed via the targeted participants' social media pages such as Facebook, WhatsApp and email so as to cut the costs of travelling over long distances to meet them in person. Distributing via the Omni-channel platforms also increased the convenience of data collection as the respondents filled them at their free time. The questionnaire comprised open ended and closed ended questions (See appendix 1). Open-ended questions were effective in gaining in-depth response to the questions while the closed ended questions were helpful in determining the diffusion rates of various aspects of GBT. As Wang (2015) explain, combining open ended and closed or structured questions always generate better results than using either of the approach alone. For the closed ended questions, a five-point Likert-type scale and ranking was used that that ranged from strongly agree to strongly disagree. The questionnaire had four sections namely: Section A collected demographic information such as the respondents' profession, educational levels, gender and experiences. Section B sought for information on the trends in the adoption of GBT and their

effects on energy efficiency of the high- rise buildings in Karura area. Section C concentrated on the factors affecting the incorporation of GBT into the ongoing high-rise buildings in the study area. Section D focused on the various challenges facing the stakeholders in the shift to GBT while Section E covered the strategies for promoting green construction concepts.

3.6. Data Collection Procedures

The researcher first sought permission to conduct the study from various authorities (CUEA, NACOSTI and the management of the studied construction firms). Online questionnaires were then sent to the targeted respondents via online platforms. The participants were allowed adequate time (one month) to fill and send back the questionnaires.

3.7. Pilot Study

The researcher conducted a pilot study to test the validity and reliability of the data collection instruments. It involved 36 respondents or 10% of the sample size. These participants were randomly selected and comprised all the targeted groups such as architects (9), engineers (1), surveyors (4), contractors (17) and property managers (4). The responses were applied in improving the entire research paper especially the data collection instruments. The respondents were asked to express their views on the questionnaire items that did not make sense, were ambiguous or that needed improvements.

3.7.1. Reliability

All the research instruments (tools) were pre-tested before the actual study. The test-retest approach was employed to aid in ascertaining the validity of the instruments. Everitt & Skrondal (2010) defines reliability as a tool for assessing the consistency of a data collection instrument. The first test was conducted during a pilot study involving 10 % of the study participants (36 individuals). The outcome of the survey helped to improve the questionnaire that was used in the final study. Pearson correlation test-retest was conducted using SPSS where the results of the survey conducted in the first week served as the baseline while the

results of the last week of the survey was the post test data. The results indicated a p-value of < 0.5 and a correlation coefficient of 0.8 indicating a high reliability (Lindstron, 2010).

3.7.2. Validity

The study also employed content validity to ensure the data collection tools were helpful in acquiring accurate information (Yin, 2017). Content validity rely on inference from test scores to explore the consistency in collected data. The researcher consulted with the expert supervisors and was guided accordingly on the questions for content validity. Moreover, the researcher trained 3 enumerators before actual data collection in order to ensure that they collected the desired data. At the same time, the research tools were counterchecked regularly for any mistakes and errors to ensure validity of data.

3.8. Data Analysis Procedures

Data was analysed using the Statistical Package for Social Sciences (SPSS) tool. First, the explorative data techniques were administered at the initial analysis stages to uncover the structure of the data and for the identification of outliers or unusual entered values. Secondly, the researcher referenced the questionnaires and coded them in readiness for data entry. Thirdly, data cleaning was conducted to eliminate the errors in entry. SPSS thereafter helped to generate descriptive statistics such as frequencies, percentages and mean score, standard deviation. Similarly, the output was presented through frequency tables and graphs.

On the other hand, conceptual content analysis helped to synthesize information from the qualitative data (Batini et al., 2021). The state of energy efficient high-rise buildings and the independent variables (factors affecting the adoption of the GBT) were quantified to gain profound insights on the GBT success in creating energy efficient high-rise buildings in Karura area. DIT and GST theoretical concepts was applied in interpreting the results vis-à-vis the study objectives. The response to each item in the questionnaire was linked to relevant theory and goals of the study. For example, the first section of the questionnaire helped to quantify

the adoption rates of GBT and how particular aspects of the building technology related to each other in creating efficient systems as emphasized in GST.

3.9 Ethical Considerations

The questionnaires did not include any personal information such as the respondent's name, contacts and physical addresses and the data was also treated with confidentiality (Adam et al., 2018). Having the respondent's details remain anonymous encouraged them to respond to the questionnaires without fear or restrictions as their response could not be tracked back to them.

The researcher also informed the respondents on their freewill to respond to the questionnaires from the start. This ensured that the respondents understood that they had the right to withdraw from the survey whenever they wished. At the same time, the researcher ensured it was a voluntary participation by the respondents, by first requesting for their consent to administer the questionnaire to them. The respondents were also informed that they were free not to take part in some aspect of the research. The respondents were also informed that their input would be used strictly for academic purposes. Furthermore, the researcher sought for authority for field work from the University Department of Social Studies and Development Studies, as well as, NACOSTI. These letters are attached as appendices.

CHAPTER FOUR

DATA ANALYSIS, PRESENTATION AND DISCUSSION

4.0 Introduction

This chapter presents the study outcomes. It also discusses the findings vis-à-vis the project's objectives. Section one of the chapter includes the respondents' demographics or background information. The demographics provides the background information about the respondents and their significance on monitoring the spread of green building technology in Karura area. Section two employ figures, pie charts and statistical analysis to summarize the key findings. While the last section employs empirical literature and theoretical framework to examine the results and their implications on the growth of construction sector not only in Karura Area but across the country.

4.1 Respondent Demographics

The study realized an overall response rate of 95% with 350 out of the targeted 367 respondents fully responding to and submitting the questionnaire. As explains Sale and Bista (2017), a response rate of at least 75% is adequate to provide the information needed to gain full insights into a phenomenon. Therefore, the fact that the study exceeded this threshold means that the obtained data was sufficient to explore the state of green building technology innovation in Karura.

4.1.1 Respondent Categories

Table 4.1 below describes the different categories of the respondents who took part in the survey and the respective response rate for each category.

Table 4. 1 Respondent's Response Rate by Category

Category	Target sample size	Actual Respondents	Percentage
Architects	89	84	94%
Engineers (Structural)	13	13	100%
Quantity Surveyors	56	53	95%
Contractors	170	165	97%
Property Managers	39	35	88%
Overall (N)	**367**	**350**	**95%**

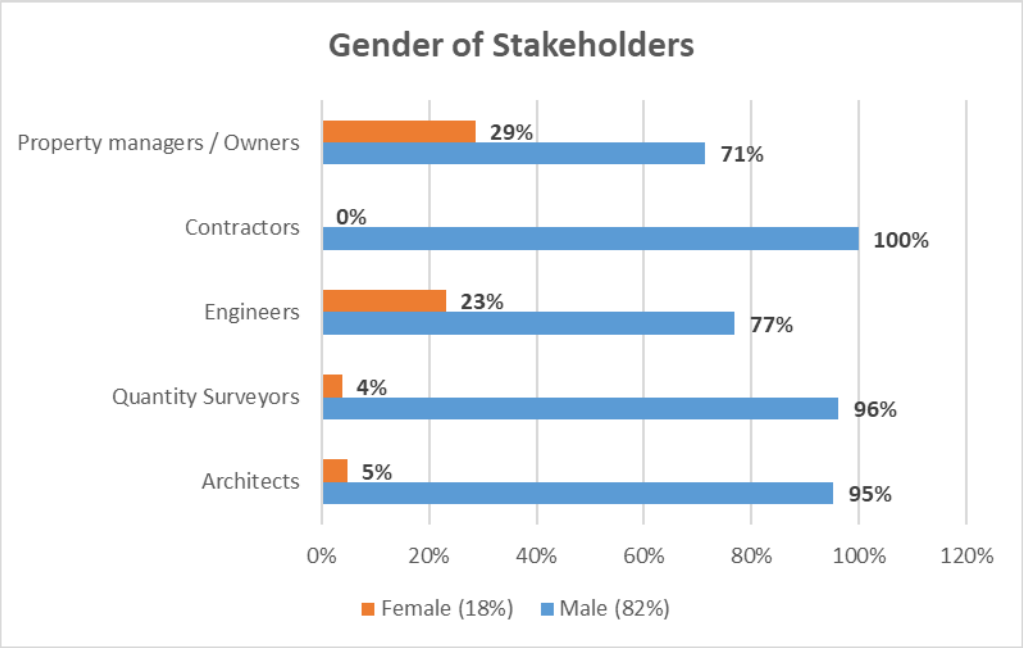
(Source: Field Survey, 2021)

The respondents included professionals from diverse areas ranging from surveyors to property managers. Consequently, they were not only privy to information relating to green building innovations but also in a position to give detailed response on the challenges affecting the technology adoption but also strategies for eliminating such obstacles and delivering desirable benefits to the tenants.

4.1.2 The Respondents' Gender

In an arguably male dominated industry, the study realized an 82% response rate from male respondents, while 18% were female respondents.

Figure 4. 1 Respondents' Gender



(Source: Field survey, 2021)

While gender may not have been one of the major factors examined in this study, it is notable from different studies that gender differences have a possibility to influence development towards a sustainable direction. For instance, a study undertaken in Sweden by Wallhagen & Sörqvist (2018) noted that females placed greater consideration and importance on environmental aspects in the building industry although they have a lower influence in the industry as compared to their male counterparts who did not have high consideration towards environmental aspects. Subsequently, this may influence to a certain level the impact of GBT on the construction industry. Therefore, the policymakers should introduce new incentives to attract more women into related professions.

4.1.3 The Respondents' Educational Background

The study also established that most respondents held a Bachelor's degree in their respective fields as depicted in table 4.2.

Table 4. 2 Stakeholders' Education Level

	Education				
	Certificate	**Diploma**	**B/Degree**	**Masters**	**Doctorate**
Architects	0%	0%	25%	75%	0%
Quantity Surveyors	0%	0%	7%	93%	0%
Engineers	0%	0%	68%	32%	0%
Contractors	1%	3%	13%	0%	0%
Property managers / Owners	35%	17%	43%	5%	0%

(Source: Field survey, 2021)

The minimum level of education recommended by the respective oversight boards for the Architects, Engineers and Quantity Surveyors is a first-degree. The study results indicate a similar finding where all the Architects, Engineers and Quantity surveyors had a minimum of a Bachelor Degree in their respective areas of practice. The academic qualification translates into increased awareness of the impacts of green building concepts on the construction ecosystem. Therefore, the input of such highly trained construction professionals was critical in achieving the study objective.

4.1.4Green High-Rise Buildings Constructed by the Respondents

Table 4. 3 Construction Projects undertaken by the Respondents

	Total Construction Projects undertaken		
	1-3	**4-6**	**7-10**
Architects	18%	72%	10%
Quantity Surveyor	42%	43%	15%
Engineer	81%	9%	10%
Contractors	74%	13%	3%
Property managers / Owners	78%	15%	7%

(Source: Field survey, 2021)

According to table 4.3, all respondents had taken part in between 1 and 10 projects in Karura area between 2013 and 2018. 18% the architects participated in between 1 and 3 projects, 72%

in 4 to 6 projects and 10% in 7 to 10 projects. The same patterns were observed for quantity surveyors. On the other hand, a significant number of engineers, contractors and home owners have participated in 1 to 3 projects but the number of houses contracted in Karura area over the study periods are lower as compared to the other professionals. This is because the high-rise buildings are time-intensive and often take several months to complete (Mulei, 2021) The architects were engaged in higher number of green building projects followed by contractors while the quantity surveyors were involved in the least number of projects as indicated in figure 4.4.

Table 4. 4 Construction Projects undertaken by the Respondents

	Green Building Projects Undertaken		
	1-5	**6-10**	**None**
Architect	63%	4%	33%
Quantity Surveyor	14%	0%	86%
Engineer	83%	17%	0%
Contractors	43%	33%	34%
Property managers / Owners	1%	19%	60%

(Source: Field survey, 2021)

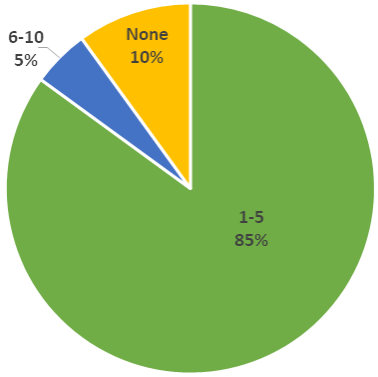
63% of the architects have participated in between 1 and 5 green projects as compared to 14% of the quantity surveyors, 83% of the engineers, 43% of the contractors and 1% of the property managers. Therefore, all the respondents have vast experience and knowledge on the green building ecosystem in the area. The trend is attributable to the fact that the real estate investors often use referral methods in recruiting the professionals (Dadzoe et al., 2021). The home owners rely on their networks to hire architects, who in turn, prefer to work with particular contractors. Since the contractors can manage several projects concurrently, they play a critical role in diffusing GBT in the area.

4.2. Research Findings

4.2.1. Adoption of GBT in High Rise Buildings in Karura Area

The study aimed at establishing the acquisition rate of GBT in high rise buildings and their impacts on energy efficiency. 85% of the respondents reported that they used the green building innovations in between one and five buildings, 5% in between 6 and 10 buildings while 10% have never employed the eco-friendly techniques as indicated in figure 4.6 below.

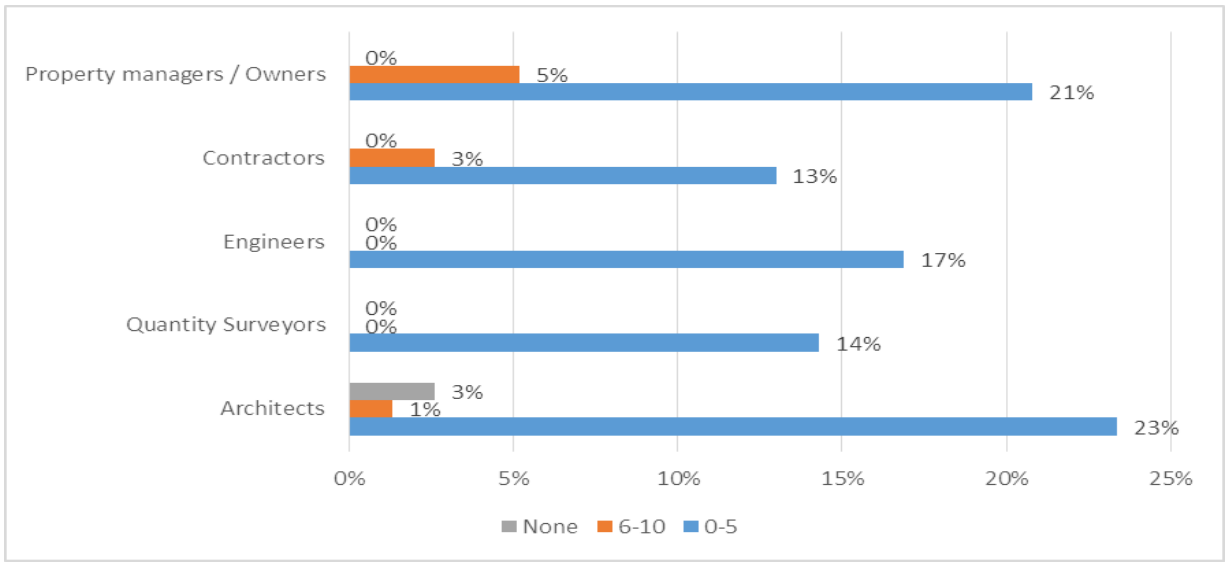
Figure 4. 2 GBT Projects undertaken by the Respondents



(Source: Field survey, 2021)

The trend indicates a positive approach towards sustainable development and growth of Karura areas' construction system. 85% means that the ecological footprint of the neighbourhood is relatively lower than those of the other areas. As Akadiri, Chinyio & Olomolaiye (2012) note, architects' designers, engineers and other construction stakeholders are now focusing on the control and correction of the environmental damage due to their construction practices through use of green building technology. This is supported by the survey outcomes as summarized in figure 4.7 that the property managers and owners have adopted green building technology in their buildings as 5% reported to have used GBT in 6 buildings while 3% of the contractors and 1% of the architects indicated the same. This is a sign that the green building technology concept was slowly gaining acceptance in the study area.

Figure 4. 3 Number of GBT Projects undertaken by the Respondents



(Source: Field survey, 2021)

The stakeholders are slowly embracing green technology. Less than a quarter of the property managers, contractors, engineers and architects have constructed fully functional green high rise building over the study period. While about 5% of the owners have participated in 6 -10 green projects. However, the results indicate positive performance as high-rise buildings are long term projects that may take several years to complete. The progress means that the industry is making remarkable progress towards achieving sustainable development goals.

The results in table 4.5 further indicates that respondents are embracing various aspects of GBT to achieve leadership in energy consumption and environmental design.

Table 4. 5 Adoption of GBT Concepts in the Construction Industry

		S. Agree	Agree	Neutral	Disagree	S. Disagree
S1	I employed the whole-building approach to ensure that all my green building projects will consume the least possible energy	202	140	8	0	0
S2	I mostly used building materials that enables continuous insulation so as to minimize the need for energy for heating and cooling purposes	72	198	32	42	6
S3	I also employed high thermal mass and eco-friendly construction materials that stabilizes the buildings temperatures at all times	70	193	29	40	18
S4	The high-rise buildings employed alternative (renewable) energy sources like solar power and hybrid electric systems instead of the non-renewable sources	120	203	8	12	7
S5	The buildings site was strategically design to increase access to direct sun light	65	112	91	52	30
S6	The buildings used high efficiency heating and cooling systems with the major equipment having energy star ratings	174	108	31	23	14
S7	The buildings employed smart building devices such as occupancy and motion sensors, programmable thermostats and ceiling tiles with air purification systems	80	111	50	67	42
S8	The buildings used energy recovery ventilation systems such as natural lights, as well as, exhaust fans in the wash rooms and kitchen	93	130	8	12	7
S9	The buildings have energy efficient windows and doors	76	118	56	47	53
S10	We used mostly the high efficiency heat pump water and solar water heaters in the buildings	83	119	36	70	42
S11	We used low emitting carpet and flooring system in the projects	77	112	87	42	32
S12	The waste management systems used in the projects I undertook promotes recycling and reuse of products	56	93	102	62	37
S13	Overall, we designed the buildings to ensure compliance with relevant standards such as BEAM, LEED and International Green Construction Code	205	133	12	0	0

(Source: Field survey, 2021)

The responses indicate high compliance rates with green building standards. The vast majority of the respondents leveraged various aspects of green building innovations to ensure that their projects used the least possible energy throughout the project cycle. Notable observations include the sustainable sourcing of raw materials as 163 or 46% agreed that their firms not only obtained their materials in eco-friendly ways but also employed the inputs that ensured high

thermal and continuous insulation. Only 27 respondents argued that their projects did not utilize renewable energy and hybrid electric systems. In contrast, 93 strongly agreed and 130 others agreed that their buildings were designed to make use of natural lights. 191 individuals also reported that they used smart devices such as motion sensors to conserve energy during low occupancy. Overall, 338 respondents (96%) are confident that the GBT employed in their projects would results into various benefits of low energy consumption such as minimal utility bills, comfortable and healthy indoor environmental quality and high profitability.

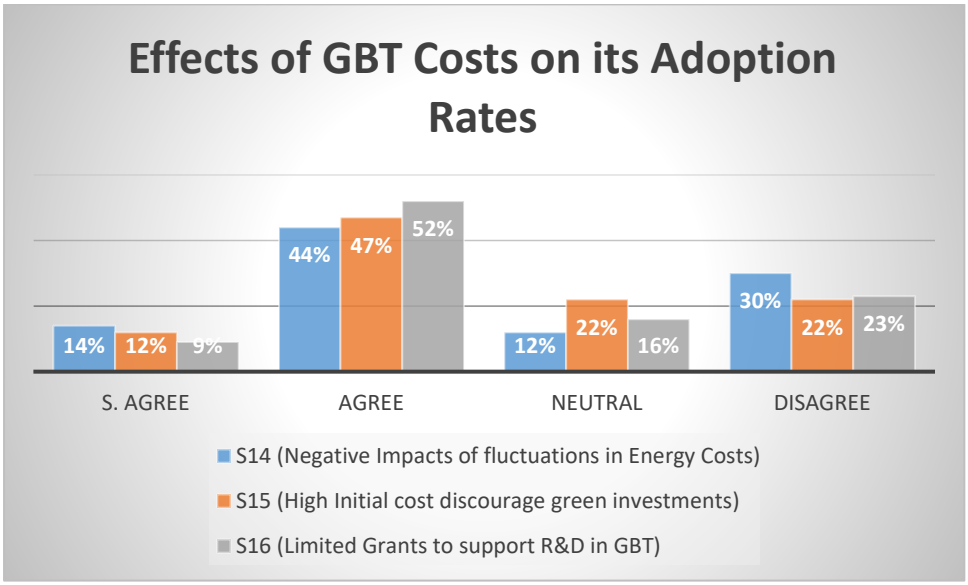
4.2.2. Factors influencing the Use of GBT in Constructing Energy Efficient High-Rise Buildings in Karura Area

The study established that the key factors influencing the use of GBT in constructing energy efficient buildings included costs of construction, awareness levels and policy gaps.

4.2.2.1. Costs of Adopting Green Building Technologies

The majority of the study participants raised concerns over the impacts of costs related to GBT on the increase in the number of energy efficient houses in Karura area. Such expenses include initial costs, and research and development on green the green innovations.

Figure 4. 4 Respondents' views on the Effects of GBT Costs on the rise in Energy Efficient High-Rise Buildings



(Source: Field survey, 2021)

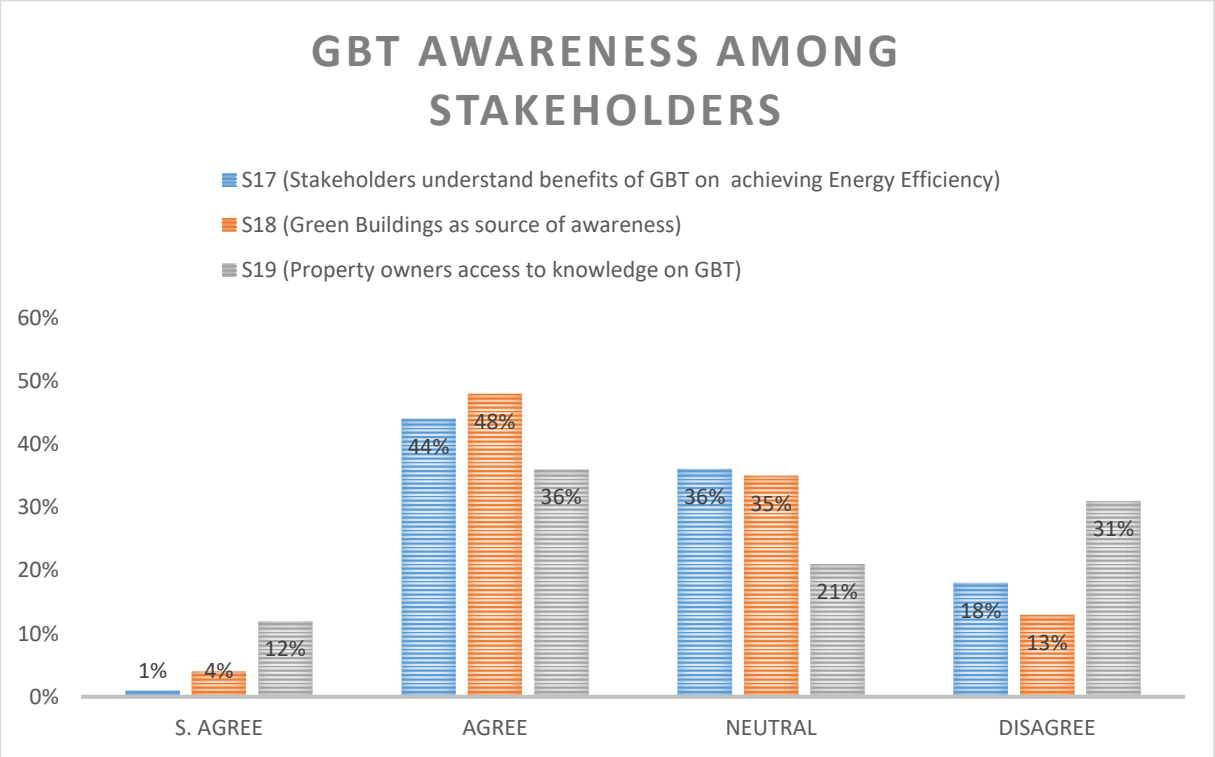
While only 22% of the respondents disagreed that the initial costs of GBT are high and unaffordable to most stakeholders, 22% were neutral 47% agreed and 12 strongly agreed. This explains why some stakeholders may be perceived as laggards while in the real sense they would wish to construct a 5-star green rated high-rise building. 61% of the respondents agreed that there was limited research on green building concepts due to costs implications while 23% disagreed. Similar challenges have been identified by several other studies (For example, the study by Agyekum et al. (2019) observed that lack of adequate educational programs on green building technology hindered the adoption of GBT in Ghana. While Addy et al. (2019) attributed the challenge to lack of adequate fiscal incentives. Like in this case, it is likely that more stakeholders would employ the most efficient green equipment and electricity systems if the government introduces better supportive programs. Currently, the construction costs are high hence GBT adoption rates is increasing but at a slow rate.

4.2.2.2. GBT Awareness Rates among the Respondents

As shown in the figure 4.9, 44% of the respondents agreed that they were aware of the GBT and their significance on the prosperity of Karura area, while 48% agreed that the green buildings themselves are sources of information on the need to shift to green ecosystem. However, the respondents argued that the awareness levels were very low among the property owners. For example, 36% of them admitted that they were not aware of the green building benefits. Similar, findings were reported in the study by Kanda et al. (2023) that mostly construction practitioners were knowledgeable on green building technologies while other stakeholders are yet to gain comprehensive understanding of the sustainable building practices. At the same time, the adoption of GBT in the entire African continent remains low. Sichali and Banda (2017) focused on the awareness, attitudes and reception of GBT in the Zambian construction sector found that mostly professionals were well-informed about the green

technologies while although the general public had knowledge of sustainable practices the awareness levels were low among the majority. The study indicated that the low number of green infrastructures in Kenya were as a result of lack of awareness, attitudes and perception of the community and professionals.

Figure 4. 5 GBT Awareness among the Stakeholders



(Source: Field survey, 2021)

The study further determined the respondents' awareness levels on various green building concepts such as conservation measures required, vegetation preservation, retrofitting of old electrical fittings, use of eco-friendly (low emitting) carpet and floor and waste management plans. Table 4.6 displays the result

Table 4. 6 Stakeholder's Awareness on Green building Concepts

Awareness on Green Building Concepts	Disagree	Neutral	Agree	Strongly Agree
Green sourcing of appropriate and eco-friendly materials	16%	34%	42%	8%
Site design in terms of presence of natural factors such as lights and vegetation	12%	35%	45%	8%
High efficiency HVAC system	14%	35%	39%	12%
Low emitting carpet and flooring system	9%	31%	34%	26%
Smart building devices and waste management system	5%	31%	35%	29%

(Source: Field survey, 2021)

About 50% of the study participants were unsure of the conservation measures needed to construct a 5-star green status hence there is need to improve on knowledge dissemination on the area. The same observation was made in regards to site design while constructing high rise building, as well as, deployment of HVAC system, use of low emitting carpet and smart devices in managing waste and overall energy use as 53%, 51%, 60% and 64% either agreed or strongly agreed that they understood the roles of the green aspects respectively on promoting energy efficiency.

4.2.2.3. GBT Legal Frameworks and Governmental Intervention

The study respondents also expressed their views on the roles played by the local authorities on promoting green building practices in Karura area. The questionnaire focused on a number of GBT support factors such as urban planning, green checklist, existence of supportive regulatory frameworks, financial incentives, research and development among others.

Table 4.11 summarizes the responses.

Table 4. 7 Local Authorities Roles on Promoting GBT

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.	There is inadequate Urban planning and land use Policy	6%	31%	13%	43%	6%
2.	The local authority has established a comprehensive green check list	14%	57%	8%	18%	3%
3.	The govt. has enforced relevant laws on GBT	17%	29%	12%	29%	14%
4.	The sustainable building policies are inadequate	1%	30%	4%	43%	22%
5.	Mandatory building audits have been introduced	19%	34%	29%	18%	0%
6.	The government offer financial incentives	19%	40%	9%	27%	4%
7.	Supportive urban land and Planning Policy is in place	18%	47%	17%	17%	1%
8.	The authorities promote GBT adoption through green building compliance certificates	35%	39%	14%	12%	0%
9.	The authorities offer R&D support	5%	27%	3%	57%	8%
10.	Karura area has integrated policy framework on GBT	21%	38%	18%	23%	0%

(Source: Field survey, 2021)

Table 4.7 indicates that the governmental support has been underwhelming in most of the cases with only 23%, 21%, 18% and 12% of the respondents agreeing that Karura area has integrated policy framework, sustainability checklist, urban land and planning policy, and issuance of compliance certificate respectively. At the same time, 43% of the individuals agreed and 22% others strongly agreed that the sustainable building policies are inadequate. Overall, 65% agree that the government should move with speed in enforcing comprehensive frameworks to entice more stakeholders to embrace GBT.

4.2.3. Challenges undermining the Use of GBT in establishing Energy-Efficient High-Rise Buildings in Karura Area

The respondents reported the major barriers to incorporation of GBT into establishing high performance high-rise buildings. Table 4.8 depicts the responses to the specific factors hindering the deployment of the relevant technologies in achieving energy efficiency.

Table 4. 8 Challenges hindering the shift to GBT and related Energy Efficient Technologies

Challenges cited	Frequency	Percentage
Initial capital required is too high	17	22%
High servicing and maintenance costs	17	22%
Low awareness level/ ignorance on GBT	15	19%
Inadequate supply of trained professionals	10	13%
Lack of political will to embrace green building	7	9%
Costly GBT Equipment	6	8%
Governance issues (lack of transparency in acquiring green certification and access to support programs)	5	6%

(Source: Survey, 2021)

It was established that 22% of the respondents considered the costs of implementing and servicing green building to be too high and it is a key challenge in achieving energy efficiency in the industry. 19% of the respondents argued that low awareness level or ignorance hindered their shift to eco-friendly high-rise buildings. In addition, lack of political will was also mentioned by 9% of the respondents while 6% cited inadequate governance structures, which in turn, promote corrupt practices in following due processes and ensuring compliance with expected green building standards.

4.2.4. Strategies for Promoting the Shift to Energy-Efficient High-Rise Buildings in Karura Area

The respondents further expressed their views on the best intervention strategies. These included whether interventions such as introducing new laws, awareness programs, tax rebates, and regulating material prices would enhance the shift to green high-rise buildings. Table 4.9 lists the mitigation measures as suggested by the respondents.

Table 4. 9 Proposed Intervention Strategies

Suggested mitigation measures	Frequency	Percentage
Ensuring proper and strict laws are laid out to reduce costs and corruption	22	29%
Creating awareness of green building technology	18	23%
Government involvement in offering tax rebates and other incentives	13	17%
Teaching and integrating GBC policies and benefits in training institutions	13	17%
Regulation of market prices & costs for green building	11	14%

(Source: Field survey, 2021)

4.3. Discussion

From the perspective of DIT, the respondents can be categorized as innovators, early adopters, early majority, late majority and laggards (Mahajan, 2010). The innovators refer to the respondents that are actively involved in revolutionizing the industry through new green building concepts. For example, 17 engineers, 33 contractors and 19 property managers who have actively participated in the construction of more than 6 green buildings over the study period. These stakeholders are employing the technologies to increase the supply of energy efficient high-rise buildings throughout the study area. The Study indicates that the industry's acquisition of GBT is growing slowly but steadily. At least 20% of the respondents reported to have participated in construction of between one to five green high-rise buildings. Given that such houses are time intensive projects that often takes several months or years to complete, the results indicate a remarkable growth of the green infrastructures.

At the same time, the researcher's tour around Karura neighbourhood revealed that there was influx of alternative energy sources, use of sustainable construction materials and improved indoor quality in an increasing number of buildings. A good example is Dunhill Towers that was awarded a 5-star green status in 2017 (Kagai, 2017). It became the first house in the entire East Africa to install advanced green features. Dunhill was a pace setter in various dimensions such as energy and water efficiency, and tapping of natural light. The accolades have encouraged several other early adopters. Although many buildings have 3 star or lower green

ratings, there are partial adoption of eco-friendly initiatives such as solar power, and resource-efficient designs. Many of such buildings have high performance glass, energy saving lighting, automatic lighting controls for corridors and stair cases, occupancy sensors in bathrooms, bedrooms, low-flow faucets in bathrooms and many others (Kivuva, 2022). These are pieces of evidence that the architects, surveyors, engineers and property managers are embracing the technology. The respondents are actively involved in installation of such facilities. 95% of the respondents reported that they always use low power electrical bulbs. As a result, the performance of their final projects is high. The buildings' energy consumption ais not only lower than those of conventional storied buildings but are also decreasing over time. Emergence of advanced technologies such as automated electricity systems results into better ways for achieving energy saving. This was in line with the study by Magno et al (2015) that established that light accounts for a large share of energy consumption hence use of smart LED alternatives was essential in addressing the concern. 71% of the participants also revealed that they often fit solar panels in their projects while 75% always install solid waste system. However, the adoption rate of eco-friendly environmentally friendly materials and large-scale landscaping in preservation of natural resources were practiced by 53% and 47% of the respondents respectively.

Despite the green building concepts being in existent for decades, the industry is also characterized by both the late majority and laggards. In fact, while other cities began shifting to green building technologies by early 1990s, few high-rise buildings can be categorized as energy efficient (Wang et al., 2019; Kimani and Kiaritha, 2019). In China for example, GBT is part and parcel of all new buildings right from site planning to periodic renovations (Wang et al., 2019). In contrast a significant number of the participants (10%) are yet to incorporate these tried and tested technologies into their buildings. The negative attitudes are due in part to low awareness rates, as well as, negative perceptions. The results indicate that about half of the

respondents were not knowledgeable on GBT. However, only 53%, 51%, 60% and 64% have deployed HVAC system, used low emitting carpet and smart devices in managing waste and employed other GBT to achieve overall low energy use respectively. Arguably, these are the laggards who are still sceptical of the changes resulting from the shift such as whether they would recoup the high initial costs of greening their buildings. In the view of Dadzoe et al. (2021), the emotional experiences and cognitive judgements are yet to induce positive mindedness that the GBT would yield cost and resource efficiency in the long run. The stakeholders, therefore, are hesitant to embrace the technologies. However, study by Kimani and Kiarithia (2019), found that every 2% of the costs invested in the green projects at the initial phases results to over 20% increase in life cycle savings. 38% of the respondents are yet to adopt air conditioners and ventilation systems and 40% need to adopt better strategies for recycling water.

General systems theory further provides explanations on the observed patterns between green building adoption and energy efficiency. The approach argues that factors affecting the stakeholders' use of GBT, challenges involved in the switch to green infrastructures and intervention strategies influences the popularity of the technology which, in turn, increases the overall energy efficiency or performance of the high-rise buildings in Karura area (Kibert, 2016). The theory views the elements together as a whole instead as independent factor. The adoption rate of GBT can thus be regarded as function of the cost, awareness level, government support, access to professional construction stakeholders, as well as, the intervention measures. In other words, each challenge should be matched with appropriate intervention strategy in order to foster rapid acquisition of the green building technologies. However, this was not the case in Karura. From the perspectives of the majority (60%) of the respondents, limited research exists on GBT and 44% lacked first-hand information on the advantages of green building over conventional housing facilities, as far as, energy efficiency is concerned. On the

other hand, there is underwhelming support from the government. Results indicate that less than a third of the respondents were satisfied with the local government's commitment to greening Karura area. In fact, only 23%, 21%, 18% and 12% of the respondents agreed that Karura area had integrated policy framework, sustainability checklist, urban land and planning policy, and issuance of compliance certificate respectively. Previous pieces of evidence indicates that Kenyan construction industry is developing at a slower rate as compared to advanced economies with high concentration of green infrastructures due to the gaps in the legal frameworks and research and development. Zhao et al. (2015) argued that lack of user-friendly economic models for monitoring and comparing the costs against the benefits of particular GBT undermines their applications. Such a concern was also observed in Karura area. Mulei (2021) also showed that China is a world leader in green infrastructures because of the continuous investments in innovative policy frameworks by the national government. This study results suggest that incentives are not yet enough to foster steady growth of GBT. Consequently, the energy efficiency of only the green building meet expectations. In contrast, the ecological footprint, energy expenditure and greenhouse gas emissions of most of the high rise building still pose serious change to climate change.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION OF THE STUDY

5.0 Introduction

The chapter first draws conclusions from the main findings of the study then discusses their future implications on research, practice and theory. It further provides recommendations on the interventions needed to achieve continuous benefits from embracing GBT.

5.1. Summary of findings

5.1.1. Adoption Rate of GBT on High-rise Building in Karura Area

The study found that the green infrastructure is expanding rapidly across Karura area thereby improving the energy efficiency of a growing number of high-rise buildings in the neighbourhood. 85% of the respondents reported leveraging green building technology in improving the energy consumption of at least 5 of their last construction projects. While GBT has featured in more than 5 construction projects undertaken by at least 5% of the respondents. The adoption of the eco-friendly technology is expected to maintain steady growth in Karura and across the country over the foreseeable future. As a results, a high number of stakeholders are enjoying quality indoor air, low utility bills and enhanced overall welfare.

5.1.2. Factors Influencing GBT Adoption

The growth of energy efficient high-rise building is affected by multiple factors. However, the respondents reported cost of construction, awareness rates, as well as, legal frameworks and government interventions as the most significant factors impacting on the quest to establishing energy efficient high-rise building. 61% of the respondents agreed that the cost can hinder the popularity of GBT especially if the expenditures are higher than conventional high-rise buildings. On the other hand, 58% argue that the rising energy costs can motivate the stakeholders to opt for green building concepts such as solar panels. At the same time, 31% of

the property owners believed that inadequate flow of information can adversely affect the use of GBT yet they are key decision makers in the kind of investment they desire to achieve.

5.1.3. Challenges Facing Adoption of GBT

The results of the factors affecting the acquisition of GBT are consistent with those of the factors influencing the spread of the eco-friendly practices in Karura area. The challenges include inadequate awareness, limited supply of GBT-savvy professionals and lack of sufficient support by the national and local authorizes. For example, 22% of the respondents perceived that the initial capital, as well as, servicing and maintaining the equipment were higher than the traditional buildings. However, this is not always the case as the owners' gains higher profits from the green infrastructures in the long run. The study findings suggest that the accumulated benefits such as cost savings, energy efficiency and better quality of air exceed the costs by high margin. The energy bills of the high-performance buildings are 40% lower than the traditional housing facilities.

5.1.4. Intervention Strategies

Several strategies were found to be effective in promoting GBT in Karura area. First, 29% of the respondents advocated for the need to introduce good and valuable policies to govern the construction of green buildings. Secondly, 23% believed that creating awareness on green building technology via all the available channels would go a long way in increasing its acquisition particularly by the property managers. Moreover, regulation of market prices and costs of building materials that are used in constructing green buildings was also advocated as an intervention measure by 14% of the respondents.

5.2. Conclusion

The study concluded that adoption of GBT in the construction industry is significantly impacting on the energy efficiency of the high-rise buildings. The shift to renewable energy sources coupled with sustainable building materials is eliminating a number of challenges that

have affected construction industry stakeholders in Karura area for decades. The increase in supply of energy efficient high-rise buildings is not only playing critical roles in environmental conservation but also enhancing the socioeconomic prosperity of the stakeholders. The residents are spending lower proportion of their income on power bills Use of GBT by 85% of the respondents in constructing energy efficient storey buildings also means that thousands of Karura Area residents are enjoying quality air, low energy budgets and reduced prevalence of health conditions caused by the high greenhouse gases emitted by the conventional storey buildings.

However, a number of barriers such as high initial costs, low GBT awareness rates and inadequate legal frameworks still pose significant challenges to ensuring sustainable growth in the supply of the energy efficient high-rise buildings in the area. In fact, 22% of the respondents showed pessimistic attitudes towards the country's ability to match the records of the advanced economies, as far as, the shift to green infrastructures is concerned. The majority of the stakeholders are further urging the government to move with speed in launching timely policies, economic packages and awareness programs.

5.3. Recommendations

The construction stakeholders in Karura area, as well as, across Westlands and Nairobi Metropolitan Area require well-coordinated support in order to foster consistent and rapid adoption of GBT. Therefore, the authorities concerned should undertake the following steps:

5.3.1. Theory

The study found that late majority and laggards are still sceptical of the benefits of green buildings over the conventional housing facilities. The reluctance can be eliminated through aggressive awareness programs launched via Omni-channel platforms to foster positive attitudes towards the green innovations. Empirical evidence indicates that trade shows and exhibitions, campaigns via social media platforms, television and radio programs are essential

tools for promoting acquisition of SDGs throughout the globe (Wang et al., 2019; Cao et al., 2022). As the study indicates, a good number of the stakeholder's lack access to timely information due to the lack of appropriate programs to advocate for behavioural change. Therefore, the stakeholders should move with speed in addressing the knowledge gap.

Like in the advanced economies such as China and the Netherlands, the GBT diffusion incentives should entice the private developers, real estate agents, architects, surveyors to embrace the practice. According to Kinoti (2017), partnerships between the local authorities and private investors are needed. For example, Kenya Green Building Society can partner with the leading industry players such as Cytonn and other real estate agents to survey Karura and neighbouring regions for the green buildings. They can apply various standards such as BEAM to label the building and issue press briefings emphasizing on the advantage of the green certified buildings over the traditional houses (Kibert, 2016).

Countrywide promotional programs where the features of exemplary green buildings such as Dunhill are showcased through all the available media platforms would go a long way in encouraging the shift to green infrastructures (Kapoor et al., 2019). The lead players in such projects including the architects, engineers and surveyors should also be rewarded through both financial perks and non-monetary incentives such as endorsement deals, scholarships to further their education and chances to participate in high profile conferences by the United Nations and other world leading agencies.

5.3.2. Management and Practice

The findings imply that the construction firms should adopt new incentives for enhancing the cost advantages of GBT in terms of the quality of the life of the occupants, ecological footprint, environmental preservation and savings on energy consumption and building maintenance costs would accelerate GBT diffusion (Cao et al., 2019). The firm's executives should collaborate in promoting research and development. For example, the stakeholders can

collectively create a database for monitoring the energy efficient building's periodic performance as compared to the regular high-rise properties. Experts including scholars, professional builders, engineers, architects, surveyors and house owners can further organize regular webinars, seminars and conferences to discuss the latest GBT trends. A study by Yeats et al. (2017) demonstrated that such knowledge sharing programs allowed rapid adoption of energy efficient technologies in the Netherlands. The forums should be dedicated to customizing the emerging green technologies in line with the specific environmental factors around Karura area and other regions. Consequently, the new building owners would simply compare and contrast the statistics or the data collected and make informed decisions.

5.3.3. Policy Reforms

Appropriate and timely legal frameworks present sustainable solutions to all the identified challenges to acquiring GBT. The high initial costs for constructing green buildings would significantly be reduced through subsidies on environmentally friendly construction materials. In China, charging higher costs for the permits for constructing regular buildings than the green housing facilities encourages adoption of GBT (Wang et al., 2019). Policy makers such as National Construction Authority and KGBS should adopt similar policies. The authorities should introduce tax rebates, exemptions, and reliefs on solar panels, green heating, ventilation and air conditioning systems and other raw materials for the green buildings (Cao et al., 2022). In addition, the national government should work hand in hand with the financial institutions such as Housing Fund Corporation to introduce lower interest rates on mortgages on green high-rise buildings.

Similarly, unlimited support by the local government would be solved through enrolling a nationwide GBT policy framework mandating various agencies to move with speed in investing in relevant green infrastructures and entrepreneurial ecosystem. National Construction Authority can benchmark its policies against those of industry leaders such as

Netherlands. The Dutch government achieved its exemplary performance tag from the holistic approaches to encouraging eco-friendly investments (Zhang et al., 2019). The country has unlimited opportunities for investors in multiple sectors. For example, the policies enable the timber dealers to embrace sustainable approach such as recycling used wood, as well as, having elaborate programs for ensuring that new trees are planted to replace the old ones. The renewable energy sector also receives regular economic stimulus packages not only to introduce novel products but also lower the prices of existing commodities. Training on recycling of construction wastes further lower the overall costs of constructing new buildings. Adopting similar initiatives would certainly accelerate GBT diffusion in Karura area and beyond.

5.4. Limitations of the Study

While some targeted respondents had busy schedules, others did not have physical offices within Karura area but in other locations. In addition, as much as the participants had adequate knowledge on the latest trends in GBT, incorporation of the technologies in establishing energy efficient buildings is a rapidly evolving concept. That is, some of the current innovations are likely to rendered obsolete in the near future thereby negatively affecting the generalizability of the study findings. However, the use of digital questionnaire and snow ball technique in recruiting the study participants not only enhanced the convenience of data collection but also ensured that mostly those with vast knowledge and experience in GBT participated in the study.

5.5. Suggestions for Future Research

Despite Karura area being home to a high number of affluent private developers and real estate investors, it still faces serious barriers to adopting ecologically friendly buildings. The study findings, therefore, imply that Kenya is at risk of not achieving the SDGs within the allocated timeframes. This is because the construction stakeholders in the low-income neighbourhoods are worse-off in embracing the green innovations. Therefore, future studies should focus on

the economic, social and technological feasibility of embracing energy-efficient buildings technologies on eliminating the access to quality housing facilities in the disadvantaged areas such as Mathare, Kibera and Korogocho Slums.

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APPENDICES

Appendix I: Research Questionnaire for Building stakeholders

My name is **Valentine Owuor**, a master's student at the Catholic University of Eastern Africa, doing research on "**Adopting of Green Building Technology to improve Energy Efficiency: The Case of High-Rise Buildings in Karura Area, Westlands Constituency, Nairobi County, Kenya"**. I am, therefore, seeking for your consent to participate in the study as per the attached questionnaire. Your views will be used purely for academic purposes. All information provided will be treated with strict confidentiality and the respondent need not to disclose his/her name. You are also free to withdraw from the study at any time.

Answer all questions as indicated by either filling in the blank or ticking the option that applies.

(Please tick (√) appropriate answer)

SECTION A: DEMOGRAPHIC INFORMATION

1. What position do you hold in the construction industry?
    a. Architect
    b. Quality Surveyor
    c. Building System Engineers

        (Civil, Mechanical, Energy, Plumbing, Electrical, Structural, Technology)
        Kindly specify: _____
    d. Building contractors
    e. Property owners / Managers
2. What is your Gender:
    a. Female [ ]
    b. Male [ ]
    c. Other [ ]
3. State your highest level of education
    a. Certificate [ ]
    b. Diploma [ ]
    c. Degree [ ]
    d. Masters [ ]
    e. PhD [ ]

Others (Specify) ----------

4. How many construction projects have you undertaken in Karura area in Westlands Constituency County, Nairobi? _____ How many of such buildings leveraged GBT to achieve energy efficiency? _____

SECTION B: ADOPTION OF GREEN BUILDING CONCEPTS

i. **OBJECTIVE1: ADOPTION OF GBT IN IMPROVING THE ENERGY EFFICIENCY OF THE HIGH-RISE BUILDINGS IN KARURA AREA**

Please indicate your level of agreement with how the statements below relates to the features of the Green Building Projects you undertook in Karura, Westlands's area in Nairobi?

1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree

		1	2	3	4	5
S1	I employed the whole-building approach to ensure that all my green building projects will consume the least possible energy					
S2	I mostly used building materials that enables continuous insulation so as to minimize the need for energy for heating and cooling purposes					
S3	I also employed high thermal mass and eco-friendly construction materials that stabilizes the buildings temperatures at all times					
S4	The high-rise buildings employed alternative/renewable energy sources such as solar power and hybrid electric systems instead of the non-renewable sources					
S5	The buildings site was strategically design to increase access to direct sun light					
S6	The buildings used high efficiency heating and cooling systems with the major equipment having energy star ratings					
S7	The buildings employed smart building devices such as occupancy and motion sensors, programmable thermostats and ceiling tiles with air purification systems					
S8	The buildings used energy recovery ventilation systems such as natural lights, as well as, exhaust fans in the wash rooms and kitchen					
S9	The buildings have energy efficient windows and doors					
S10	We used mostly the high efficiency heat pump water and solar water heaters in the buildings					
S11	We used low emitting carpet and flooring system in the projects					
S12	The waste management systems used in the projects I undertook promotes recycling and reuse of products					
S13	Overall, we designed the buildings to ensure compliance with relevant standards such as BEAM, LEED and International Green Construction Code					

SECTION C

OBJECTIVE 2: FACTORS INFLUENCING USE GBT IN CONSTRUCTING ENERGY EFFICIENT HIGH-RISE BUILDINGS

ii. COST OF GBT

Please indicate your level of agreement with various statements on how various aspects of green buildings costs affect their adoption in Karura, Westlands area in Nairobi?

1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree

		1	2	3	4	5
S14	Regular fluctuations of energy costs make it difficult to predict future expenses and determine the savings in utility bills to be achieved throughout the project's lifecycle					
S15	The initial cost of green investment is very high and unaffordable by many building stakeholders					
S16	The low adoption rates of green high-rise buildings are attributable to the limited grants to support research and development on strategies for employing the GBT in constructing energy-efficient building.					

iii. LEVEL OF AWARENESS OF GREEN BUILDING CONCEPTS

Please indicate your level of agreement with various statements on level of awareness of green building concepts adopted within commercial and residential buildings in Westlands's area in Nairobi?

1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree

		1	2	3	4	5
S17	Most of the stakeholders understand the benefits of green building concepts and their impacts on energy efficiency					
S18	Green buildings under construction are sources of awareness on the importance of energy-efficient buildings.					
S19	The property owners are knowledgeable on the advantages of applying GBT on achieving energy efficiency					

From my experience during the projects, I noted that my colleagues understood the relevance of the following aspects of green buildings on minimizing the energy consumption of the high-rise buildings

1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree

		1	2	3	4	5
S20	Green sourcing of appropriate and eco-friendly materials					
S21	Site design in terms of presence of natural factors such as lights and vegetation					
S22	High efficiency heating, ventilation and air-conditioning system					
S23	Low emitting carpet and flooring system					
S24	Smart building devices and waste management system					

iv. GBT Legal Frameworks and Governmental Intervention

Please indicate your level of agreement with how the statements below relates to the existing legal framework on green building technology in Karura Area?

1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree

		1	2	3	4	5
S25	There is inadequate Urban planning and land use Policy					
S26	The local authority has established a comprehensive green check list					
S27	The govt. has enforced relevant laws on GBT					
S28	The sustainable building policies are inadequate					
S29	Mandatory building audits have been introduced					
S30	The government offer financial incentives					
S31	Supportive urban land and Planning Policy is in place					
S32	The authorities promote GBT adoption through green building compliance certificates					
S33	The authorities offer R&D support					
S34	Karura area has integrated policy framework on GBT					

SECTION C: OTHER CHALLENGES UNDERMINING USE OF GREEN BUILDING TECHNOLOGY IN IMPROVING ENERGY EFFICIENCY OF THE HIGH-RISE BUILDINGS IN KARURA AREA

1. Please indicate some of the challenges that come with implementation of GBT construction in the country:

_____
_____
_____
_____
_____
_____

SECTION D: STRATEGIES FOR PROMOTING CONSTRUCTION OF ENERGY EFFICIENT HIGH-RISE BUILDINGS IN KARURA AREA

2. What are some of the mitigation measures or solutions that you would consider in resolving the challenges stated above?

_____
_____
_____
_____
_____
_____
_____
_____

Thank You for Your Participation

Appendix II: Study Map



Appendix III: NACOSTI Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

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Date of Issue: 12/November/2021

RESEARCH LICENSE



This is to Certify that Ms.. Valentine Achieng Owuor of Catholic University of Eastern Africa, has been licensed to conduct research in Nairobi on the topic: ADAPTING GREEN BUILDING TECHNOLOGY FOR ENERGY CONSUMPTION IN KENYA: A CASE OF HIGH-RISE BUILDINGS IN KARURA, WESTLANDS CONSTITUENCY, NAIROBI COUNTY, KENYA. for the period ending : 12/November/2022.

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Appendix Iv Data Collection Letter

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+254-722 509811/2, 0724-253733/4
Fax: 254-2-891260

FACULTY OF ARTS AND SOCIAL SCIENCES

14th September 2021

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

RE: M.A DATA COLLECTION LETTER FOR:
VALENTINE WENDY A. OWUOR REG. NO. 1028923

The above mentioned person is a post graduate student at THE CATHOLIC UNIVERSITY OF EASTERN AFRICA (CUEA) in the Faculty of Arts and Social Sciences. She is pursuing a Master's degree in Development Studies.

Her research Proposal Topic is: ***"Adapting Green Building Technology for Energy Consumption in Kenya: A Case of High-Rise Buildings in Karura, Westlands Constituency, Nairobi County, Kenya.***

The Supervisors are: Dr. Stephen Atsatsa (PhD)
Mr. Evans Wabwire

I therefore request you to grant her permission to collect data. In case of any further information, please do not hesitate to contact the undersigned.

Thanking you in advance.

Yours faithfully,

Catholic University of Eastern Africa
Head of Department
Social Sciences
P.O. Box 62157 - NAIROBI
14/9/2021

Bernard Ndonga
HoD, Social Sciences and Development Studies

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