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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

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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 study'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 study adopted descriptive research design. 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 V.26. 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.*

Key words: *Green Building Technology, Energy Consumption, Energy Efficiency and Environment Quality*

1.1 Study Background

High energy consumption by the construction industry poses severe economic, social, environmental and health risks. The adverse impacts of the unsustainable consumption of energy is distorting the ecosystem through dangers such as global warming (Batini et al., 2021). As a result, there is consensus that the rapid deployment of the eco-friendly technologies would be key to accomplishment of multiple sustainable development goals (Kapoor et al., 2019; Sangori et al., 2020). Experts recommend the adoption of GBT (Chen et al., 2021). These include green innovations such as smart heating, ventilation and air conditioning (HVAC) equipment. It also 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.

Eco-friendly High-rise buildings are better positioned than the traditional housing facilities to deliver the targeted SDGs (UNEP, 2020). This particularly because such high performance buildings are capital intensive and require investments in technologies that few low rise buildings stakeholders can afford. At the same time, 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. However, 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). 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 18^{th} out of 111 countries for energy efficiency by the World Bank (Banerjee et al., 2017).

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**).**

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 generations. The demand for energy particularly among the occupants of high-rise buildings are rising beyond the sustainable levels**.** The storied buildings are also leading sources of toxic gases. For example, construction supplies such as aluminium, cement, steel and concrete embodied energy content (Khoshnava et al/, 2018). The manufacture of HVAC systems also emit toxic compounds such as halons and chlorofluorocarbons. Moreover, the buildings often create urban heat island, as well as, 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 Kenyan 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 areas 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 forests 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 Study 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.

1.4 Justification

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.

1.5 Literature Review

Theoretical Framework

The study was anchored on diffusion of innovation (DIT) and general system theories (GST). DIT developed by E.M. Rogers in 1962, explains the spread of disruptive or innovative product, technology or idea from the inventor to other stakeholders across the industry (Shibeika & Harty, 2015). In the construction industry, the inventions may include artificial intelligence powered smart energy systems.

So far, several researchers have employed DIT to study the impacts of GBT on the carbon footprint of the construction industry. For example, 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. GST is also a popular theory developed by Talcott Parsons and Niklas Luhmann in 1935. It view phenomenon as a complex systems 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.

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. 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.

Empirical review

Several scholars have studied the diffusion of GBT. The empirical data collected over the years lays a strong background for the study. A systematic literature review by Wuni et al. (2019), provides evidence that the influx of GBT has been necessitated by the success rates of recycling and circular economy in lowering wastage of scarce natural resources and reduction of greenhouse gas emissions. The research reviewed 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. Similar motives drives the adoption of the technology by the construction practitioners at Karura area. A study by Chen et al. (2021) also concentrated on the evolution and spread of GBT across China. It 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. 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 emissions. The study therefore developed the following conceptual framework from the empirical literature.

1.6 Conceptual framework

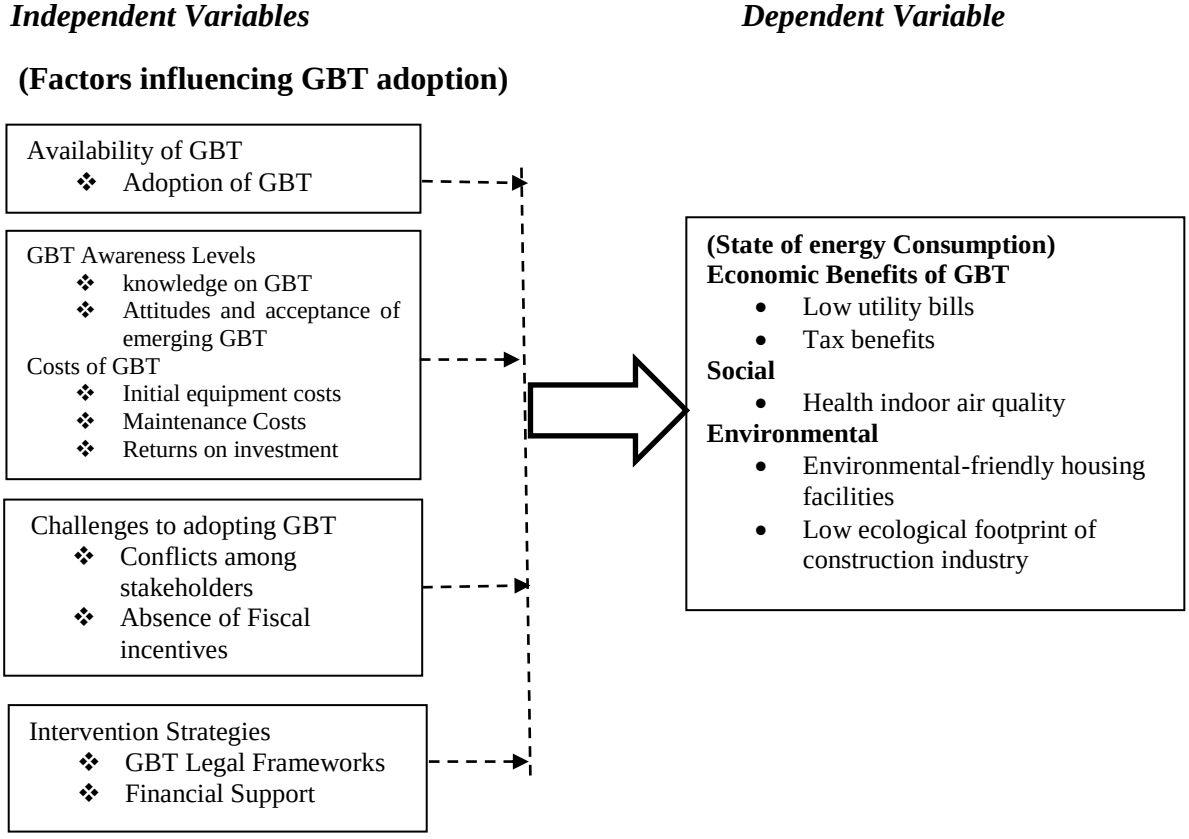

Figure 1: *The conceptual framework*
Source: *Author, 2023*

1.7 Research Methodology

The study 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). The target population included all the 4392 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). Stratified and snow-ball sampling techniques were used to recruit 367 respondents. 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. The respondents answered online questionnaires that were further analysed using SPSS V 26.

1.8 Results and Findings

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 as shown in figure 2.

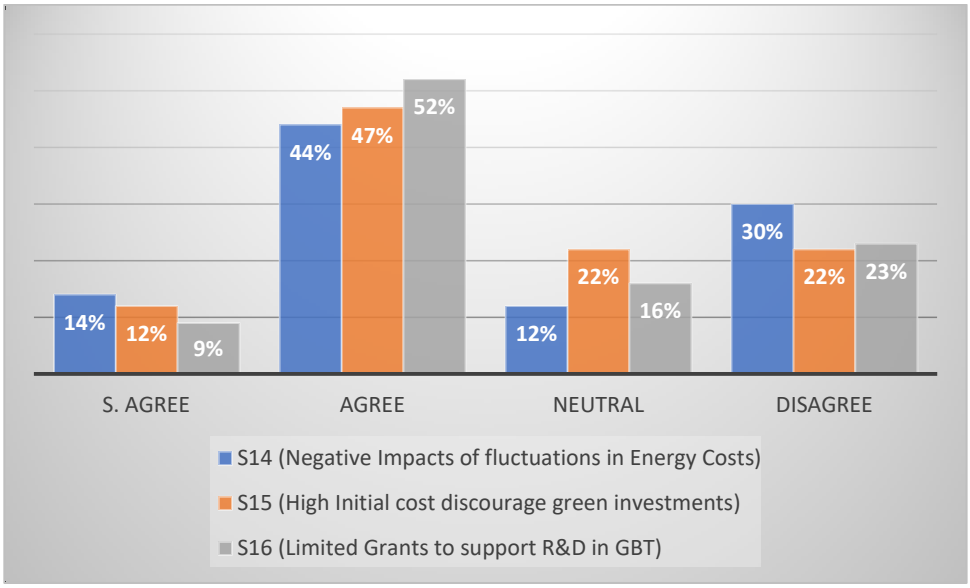

Figure 2: *Respondents views on Costs of GBT*
Source: *Field survey, 2021*

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.

GBT Awareness Rates among the Respondents

Forty four percent 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.

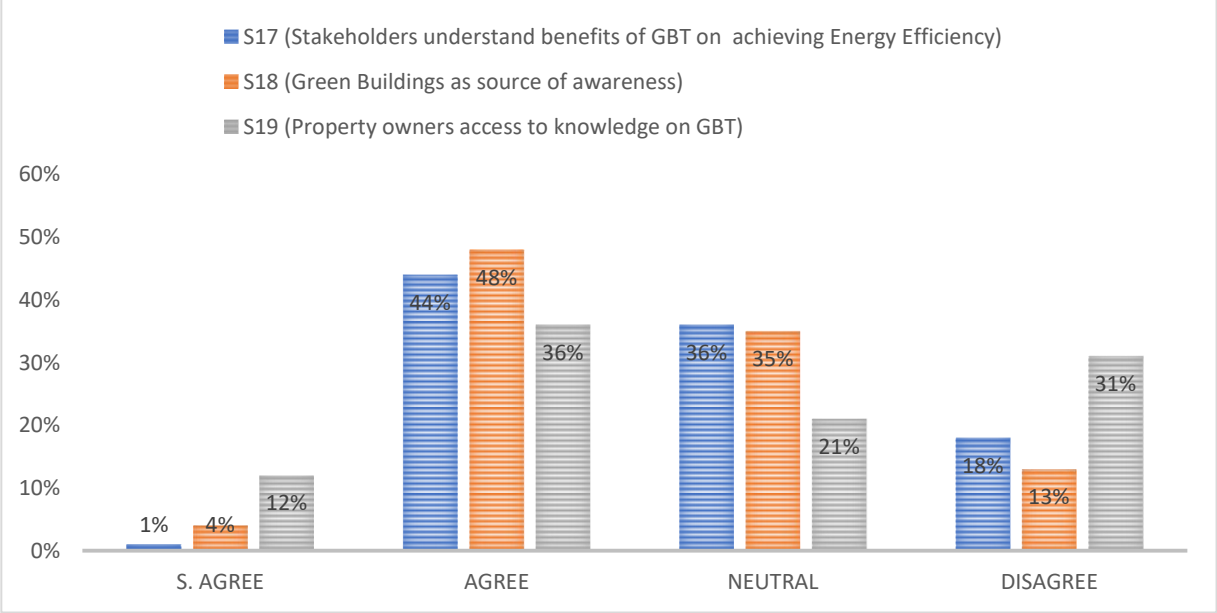

Figure 3: *GBT Awareness among the Stakeholders*
Source: *Field survey, 2021*

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 1displays the result

Table 1: 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.

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.

Table 2: Local Authorities Roles on Promoting GBT

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

Source: *Field survey, 2021*

Table 2 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.

1.9 Conclusion

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.

1.10 Recommendations

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. Similarly, appropriate and timely legal frameworks present sustainable solutions to all the identified challenges to adopting GBT. The high initial costs for constructing green buildings would significantly be reduced through subsidies on environmentally friendly construction materials. Working 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.

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