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(RESEARCH ARTICLE)

Determinants of adoption of green technologies in the construction of buildings in Nakuru city, Kenya

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Abstract

Adoption of green technologies in construction of buildings is one of the strategies of climate change mitigation and reducing the negative effects of urbanization to the environment. The adoption of green technologies is critical for achieving low carbon development. However, it is not clear what factors determine the uptake of different types of green technologies in the construction of buildings in the study area, an issue that this study sought to investigate. The study adopted a mixed research design. The target population was 1191 households, with a sample study size of 153 (13%) households obtained from Milimani, Section 58 and Naka Estates in Nakuru City. Primary data was collected using structured household questionnaires and key informant interviews. The data obtained was analyzed using descriptive and inferential statistics, where: percentages, frequencies and multiple linear regression analysis test were computed. The study observed that education level, employment status, and monthly household income had a significant influence in adoption of green building technologies. The results of the study provide a basis that can be used for the formulation of policies that can enhance the adoption of green building technologies in Nakuru City.

Keywords: Green Building Technologies; Buildings Construction; Low Carbon Development; Urbanization; Sustainability

1. Introduction

Severe droughts, rising sea levels, and depletion of natural resources, have posed significant challenges to global development [1]. The industrial revolutions of the 18th to 20th Centuries, fuelled by fossil fuel combustion, laid the groundwork for current environmental and climatic challenges. These challenges, evidenced by changes in weather patterns since the 1800s, underscore the urgent need for action to address environmental degradation and climate change [2].

The depletion of natural resources, particularly water and fossil fuels, has surpassed sustainable levels, leading to ecosystem degradation and deteriorating human health conditions [3]. Pollution, arising largely from conventional building practices in major cities worldwide, partly contributes to environmental degradation. The resulting environmental risks pose a threat to densely populated urban areas, necessitating a shift towards sustainable development practices [4].

Recognizing the critical link between environmental sustainability and economic growth, initiatives such as the European Union Green Bonds Standard aim to mobilize investment in green projects and sustainable initiatives [5]. While developed countries have made strides in environmental and climate action, developing nations, particularly in Africa, face challenges in transitioning to sustainable development. United Nation [5] report further clarifies that despite many challenges, African countries are increasingly prioritizing environmental and climate considerations in

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development projects, with sustainable buildings in many nodes gaining ground across the continent through initiatives such as green building councils.

In Kenya, the adoption of green building technologies is gaining momentum, with partnerships between local governments, industry stakeholders and local and international organizations driving sustainable development efforts. Nakuru City, for example, is collaborating with the Kenya Green Building Society and the World Bank to promote eco-friendly sustainable housing solutions. Through initiatives like the County Spatial Plan and diversification of energy sources, Nakuru is embracing green technologies to mitigate the negative impacts of urbanization and climate change [6]

However, challenges remain in the adoption of green building technologies, particularly in Nakuru City, where there is paucity of information regarding factors influencing adoption of green technologies in the construction of buildings. Yet, addressing these challenges requires a comprehensive understanding of the determinants of adoption and targeted interventions to promote sustainable construction practices. Green building technologies partly offer a promising pathway to minimize environmental impact while creating resilient, environmentally friendly infrastructure [7]. By embracing green technologies and implementing sound policies, Nakuru City can partly achieve sustainable development while mitigating the adverse effects of urbanization and climate change.

2. Research Methodology

2.1. Study Area

Nakuru City is located in the former Rift Valley Province of Kenya. It is the capital of Nakuru County and the third largest urban centre in Kenya [8]. Census Data obtained from the Kenya National Bureau of Statistics (KNBS) [9], shows that Nakuru had an urban population of 570,674, making it the largest urban centre in the Rift Valley.

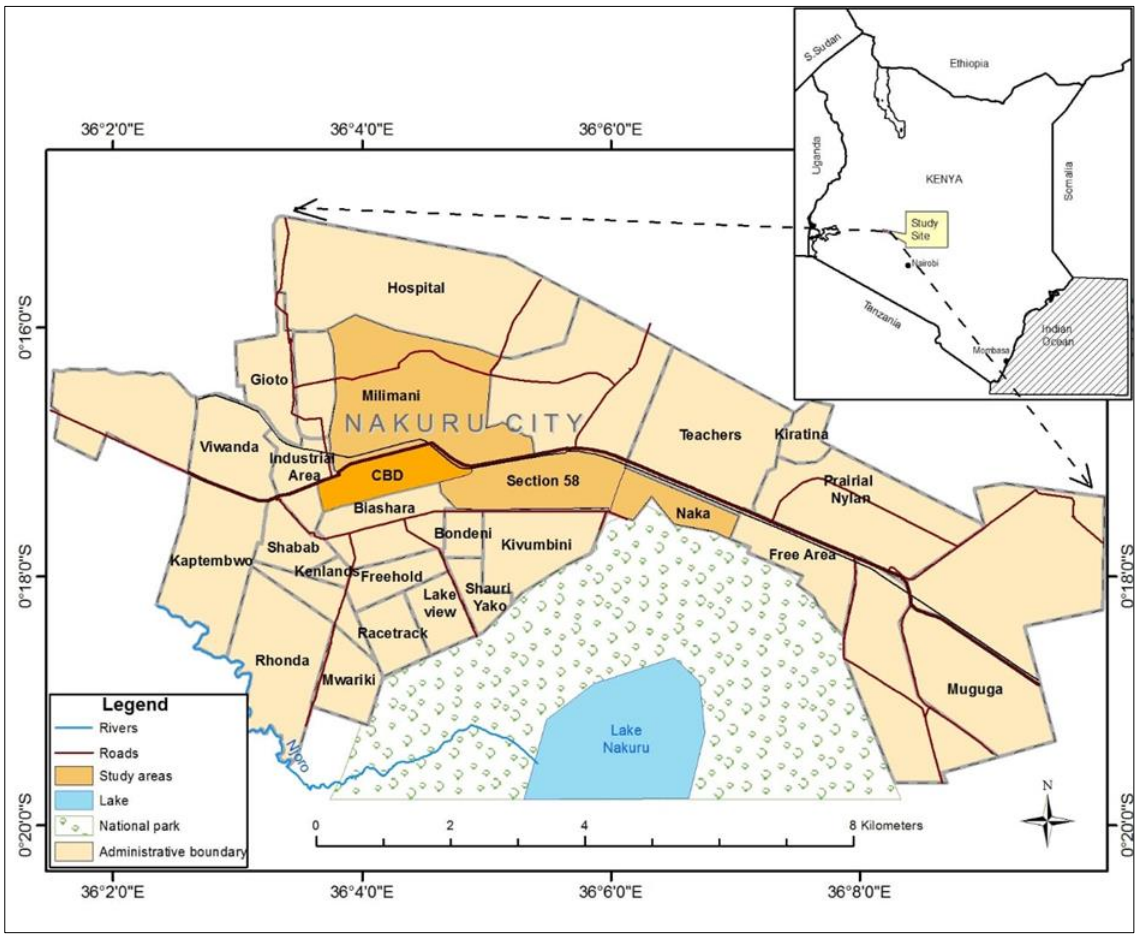

Figure 1 Map of Nakuru City Showing the Study Areas

According to Kenya Properties and Developers Association (KPDA) report of 2022, Nakuru City had a total of 11 estates with the highest ranked in terms of infrastructural development being Milimani, Section 58, and Naka. The city lies along the Nairobi–Nakuru Highway, 160 kilometres (99 miles) from Nairobi and 31 km south of the Equator, at Latitude 0°14`47``S to 0°19`32``S and Longitude 35°31`48`` E to 36°10`2``E [8]. The city is 1850 m (6,070 ft.) above the Sea level, receives an average annual rainfall of 762mm and experience an average temperature of 17.5 °C [10].

2.2. Research Design

This study employed a mixed-method research approach, as it combines aspects of both qualitative and quantitative research methodologies, allowing for a more comprehensive exploration of the research subject [11]. In applying this research methodology, the study examined several instrumental and bounded cases, utilizing multiple data collection techniques, including: structured household questionnaires; and Key Informant interviews. The sampling frames were the households within Milimani, Section 58 and Naka Estates in Nakuru City, Kenya. The target population comprised 1191 household heads. The selection of a sample size of 153 respondents, using Slovin's formula, which was included in the survey was carried out using a simple random sampling technique (using a random number generator). This method was chosen for its ability to ensure a systematic and unbiased selection of respondents whose characteristics would facilitate a thorough investigation of the research questions [11].

A structured household questionnaire was used to collect primary data. For convenience purpose, each household head was interviewed from their household. The questionnaire was subdivided into two sections which included the respondent's background information as well as factors influencing the adoption of green technologies in construction of buildings in Nakuru City, Kenya. Further, a Key Informant schedule was used to collect qualitative data. The Schedule was used to ensure uniformity during the interviews and also helped Key Informants offer a quick insight on the research questions. The data obtained was then used to supplement the results obtained from the household surveys.

3. Results and Discussion

This section highlights background information of the household heads by use of descriptive statistics (Table 1). The general bio-data generated from the respondents included their gender, age, employment status, monthly income and their education level. From the survey, 59% of the respondents were male, with 44% of the males aged between 18 to 35 years. The study also found that majority (56%) of the respondents were self-employed. It was also found that 55% of the respondents earned between KES 50,000 – 100,000 while, 69% of the respondents had attained tertiary level of education.

Table 1 Background Information of the Household Heads

Background information	Description	Frequency (%)
Gender	Male	59
	Female	41
Age (Years)	18-35	44
	36 - 55	37
	56 and Above	19
Employment Status	Employed	42
	Self-employed	56
	Unemployed	2
Monthly Income (Kes)	< 10,000	3
	10,001 - 50,000	20
	50,001 - 100,000	55
	> 100,000	22
Education Levels	No school attended	0
	Primary Education	5

	Secondary Education	26
	Tertiary Education	69

Source: Field Data, (2024)

3.1. Determinants of the Adoption of Green Technologies in the Construction of Buildings in Nakuru City

Socio-economic characteristics of a population play a crucial role in determining the extent to which households adopt new technologies, particularly in the realm of green building technologies [12]. These characteristics include the gender, age, monthly household income, education level and employment status of the household head. To better understand how these factors influence technology adoption, Multiple Linear Regression analysis was employed, providing a better view of the dynamics at play in this context, as shown in Table 2. Other determinants analyzed were: cost-effectiveness and potential savings, government regulations and incentives, market demand and consumer preferences, improved occupant health and productivity, availability and accessibility of green building materials as well as lack of awareness/knowledge about green building technologies.

Table 2 Multiple Linear Regression of Socio-Economic Factors Influencing Adoption of Green Building Technologies

Variables	**Coefficient**	**Std. Error**
Gender	0.0252	0.0398
Age	-0.2761*	0.0611
Level of Education	0.0304**	0.0413
Employment Status	0.0121**	0.0428
Monthly Household Income	0.0312**	0.0590

*, ** denote 5% and 1% statistical significance levels;**Source:** Field Data, (2024)

3.1.1. Age of the Household Head

The coefficient of age emerged as a significant factor influencing the adoption of green building technologies, at a significance level of 5%. This indicates that as individuals' age, they become progressively less likely to embrace green building technologies. Several underlying factors could explain this phenomenon. Older individuals exhibit a higher resistance to change, which can be attributed to a lifelong accumulation of habits and preferences that are difficult to alter. This population group might also have limited awareness or knowledge about the benefits and workings of green technologies, often due to lack of exposure or education on these subjects during their formative years. Additionally, the lifestyle preferences and priorities of older individuals may not align with the principles of sustainability. For instance, they might prioritize immediate cost savings and short-term financial stability over the long-term benefits offered by green technologies. This resistance to adopting new technologies is not unique to green building technologies; it is a broader trend observed in various contexts. For instance, Rokanta [13] found similar patterns in South Africa, where older individuals were noted to be more financially conservative and less willing to invest in expensive, innovative technologies. This demographic prioritizes immediate cost savings over the potential long-term financial and environmental benefits of adopting green building technologies, underscoring a significant barrier to widespread adoption among the elderly.

3.1.2. Education Level of the Household Head

Education level is another critical socio-economic characteristic that significantly influences the adoption of green building technologies. In this study, the education level of the household head showed a significant influence in adoption of green building technologies, at a significance level of 1%. This strong correlation suggests that household heads with higher levels of education are more likely to adopt green building technologies than those with lower levels of education. Education plays a pivotal role in shaping attitudes and behaviours towards new technologies. It increases awareness, imparts knowledge, offers technical support, and underscores the social, environmental, and economic advantages of green technologies. Individuals with higher education levels are generally more informed about the benefits of sustainability and are better equipped to understand the long-term advantages of investing in green technologies. This trend is supported by the findings of Quazi and Talukder [14], who observed that in Australia, individuals with tertiary education levels were more likely to adopt new technologies. Education fosters a favourable attitude towards technological advancements, making educated individuals more open to adopting innovations like green building

technologies. Furthermore, education can enhance individuals' critical thinking and problem-solving skills, enabling them to better assess the benefits and feasibility of adopting new technologies.

3.1.3. Employment Status of the Household Head

Employment status is another significant factor influencing the adoption of green building technologies. The study found that the employment status of the household head had a significant influence, at a significance level of 1%. This indicates that individuals who are employed or self-employed are more likely to adopt green building technologies compared to those who are unemployed. Employment provides a stable source of income, which is crucial for investing in green technologies that may have higher initial costs but offer long-term savings through energy efficiency and sustainability. Employed individuals typically have access to financial resources, credit facilities, and support networks that can facilitate the adoption of green building technologies. This financial stability enables them to invest in green technologies, which can lead to significant long-term cost savings and environmental benefits. The findings of Ugur and Mitra [15] support this conclusion, showing that in less developed countries, employment often provides access to financial resources and support networks that facilitate the adoption of green technologies. Employed individuals can access financing options such as green loans or energy efficiency mortgages, which help cover the initial costs of installing green technologies, making them more accessible and affordable [15].

3.1.4. Monthly Household Income

Monthly household income is a powerful determinant of the likelihood of adopting green building technologies. The study revealed a strong positive association between household income and the adoption of green technologies, at a significance level of 1%. Higher-income households are more likely to afford the initial costs associated with green technologies, such as solar panels, energy-efficient appliances, or sustainable building materials. These households often prioritize sustainability and environmental stewardship as part of their lifestyle choices. They value the long-term benefits, energy savings, and health outcomes associated with green building technologies, motivating them to invest in these technologies. Sustainability aligns with their personal values, contributing to their overall quality of life and reinforcing their commitment to environmental responsibility. Koebel *et al*. [16] found similar trends in both the United States and Africa, where higher-income households had better access to financing options for green building projects. These households are more likely to qualify for preferential loan terms, lower interest rates, and specialized financing programs designed to promote energy efficiency and sustainability. Access to financing reduces the financial barriers to adopting green technologies, making sustainable building practices more accessible to affluent households.

Similarly, this study also assessed other factors that may influence the adoption of green building technologies, uncovering several key determinants. The most dominant factor identified was the low level of awareness and knowledge about green building technologies among the respondents. Results in Figure 2, reveal that 79.1% of respondents indicated that their adoption of green building technologies was significantly impaired by insufficient information. This substantial lack of awareness can have far-reaching consequences. Without adequate knowledge, individuals are unable to access the necessary resources and information that would enable them to understand the benefits and practicality of these technologies. Moreover, lack of awareness often fosters misconceptions that green technologies are prohibitively expensive, further discouraging their adoption. These findings align with the research by Darko *et al*. [17], which highlights that misinformation and knowledge gaps can severely impede the ability of individuals and organizations to make well-informed decisions regarding the implementation of green technologies.

The second most influential factor identified was the perceived environmental benefits of green building technologies, with 41.8% of respondents acknowledging this as a significant motivator. Green building technologies are designed to reduce the environmental impact of construction and operation of buildings through energy efficiency, water conservation, and the use of sustainable materials. The recognition of these environmental benefits can drive adoption, particularly among individuals and organizations committed to sustainability and reducing their carbon footprint. The growing awareness of climate change and environmental degradation has made the environmental benefits of green building technologies increasingly appealing [18].

Cost-effectiveness and potential savings were also significant factors, cited by 38.6% of respondents. While the initial investment in green building technologies may be higher than traditional building methods, the long-term savings through reduced energy and water consumption can be substantial. These savings can offset the upfront costs over time, making green technologies a financially attractive option. The economic incentives for adopting green technologies are particularly compelling in regions where energy and water costs are high. By reducing utility bills, green building technologies can provide a return on investment that appeals to cost-conscious consumers and businesses [19].

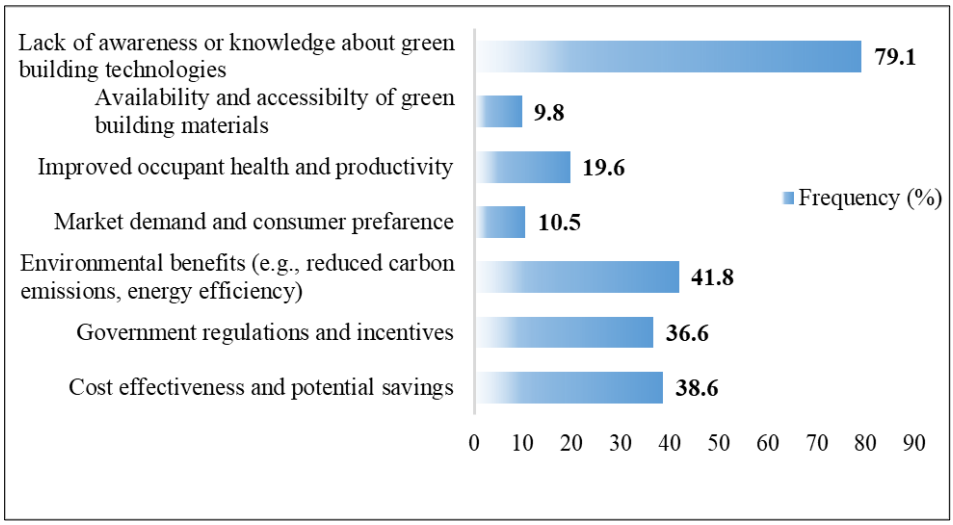

Figure 2 Factors Influencing Adoption of Green Building Technologies

Government regulations and incentives were highlighted by 36.6% of respondents as important factors influencing adoption. Regulatory frameworks that mandate or encourage the use of green building practices can drive adoption by setting standards that must be met. Additionally, government incentives such as tax breaks, grants, and subsidies can reduce the financial burden of adopting green technologies, making them more accessible to a broader range of individuals and organizations. These incentives can be particularly effective in overcoming the initial cost barrier associated with green building technologies [20].

Improved occupant health and productivity were noted by 19.6% of respondents as influential. Green buildings often incorporate features that enhance indoor air quality, natural lighting, and thermal comfort, which can lead to better health outcomes for occupants. These features can reduce the incidence of respiratory illnesses and allergies, improve mental well-being, and enhance overall comfort. Additionally, a healthier indoor environment can boost productivity, making green buildings attractive to employers who want to create a conducive work environment [21].

Market demand and consumer preference were factors influencing adoption of green technologies in the construction of buildings for 10.5% of respondents. As awareness of environmental issues grows, so does the demand for sustainable products and practices. Consumers are increasingly looking for buildings that align with their values of sustainability and environmental responsibility. This growing market demand can drive developers and builders to adopt green technologies to meet consumer expectations and remain competitive [16].

Finally, the availability and accessibility of green building materials were cited by 9.8% of respondents. The ease of obtaining the necessary materials can significantly influence the decision to adopt green building technologies. In regions where green materials are readily available and affordable, adoption rates are likely to be higher. Conversely, in areas where such materials are scarce or expensive, adoption can be hindered.

4. Conclusions and Recommendations

The findings of the study on the determinants of adoption of green technologies in the construction of buildings in Nakuru City, Kenya, reveals a complex interplay of various determinants. Factors such as gender, age, income, education, employment status, environment and the government significantly influence the adoption of green technologies to varying degrees. While some groups are more inclined to embrace sustainability, others face barriers due to socioeconomic differences, cultural norms, or lack of awareness. Despite these disparities, there is significant potential for targeted interventions to promote inclusivity and equitable access to sustainable construction practices. By understanding the unique needs and constraints of different population groups, stakeholders can develop tailored strategies to encourage adoption and overcome barriers effectively. It's recommended that the government and stakeholders should create employment across all age groups to enhance their ability to adopt green technologies. Additionally, educating the population and particularly enhancing awareness, is crucial, as higher education levels significantly influence awareness, attitude and behaviours toward green building technologies in the study area. The adoption of green building technologies is influenced by a complex interplay of factors, with awareness and knowledge being the most significant. Environmental benefits, cost-effectiveness, government regulations and incentives, occupant

health and productivity, market demand, and the availability of materials also play crucial roles. Understanding these factors can help stakeholders develop targeted strategies to promote the widespread adoption of green building technologies, ultimately contributing to more sustainable and environmentally friendly construction practices.

Compliance with Ethical Standards

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Disclosure of Conflict of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

Statement of Ethical Approval

Ethical clearance was sought from Egerton University ethics committee. Research permit was obtained from the National Commission for Science, Technology and Innovation (NACOSTI) and permission sought from County administrator in Nakuru County before the data collection exercise.

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Appendix: Household Questionnaire

I am Charles Mwangi Macharia, a student at Egerton University, pursuing a Master of Science Degree in Geography, in the Faculty of Environmental and Resource Development. I'm conducting a study on the determinants of adoption of green technologies in the construction of buildings in Nakuru City, Kenya. I seek your consent in the participation for this study as a respondent. Your participation is voluntary and all the information collected will be handled with utmost confidentiality. The results will guide policymakers and other stakeholders to identify areas where interventions are needed to achieve the desired improvements in the adoption of green building technologies.

SERIAL NO …….. ESTATE…….. DATE ……

SECTION A: DEMOGRAPHIC DETAILS

- Gender

Male	
Female	

- Age

18-35	
36-55	
56 and above	

- Household income (monthly/KES)

10,000 and below	
10,001 – 50,000	
50,001 – 100,000	
100,001 and above	

- Education level

No School Attended	
Primary Education	
Secondary Education	
Tertiary Education	

- Employment Status

Unemployed	
Self-employed	
Employed	

SECTION B: DETERMINANTS OF ADOPTION OF GREEN TECHNOLOGIES IN THE CONSTRUCTION OF BUILDINGS

- The table below shows specific green technologies used in the construction of buildings. Using a scale range of 5, rate the level to which they've been applied/adopted in your building where 1 (no extent);2 (little extent);3 (moderate extent) ;4 (high extent);5 (Very high extent)}

WATER EFFICIENT TECHNOLOGIES	1	2	3	4	5
Harvesting rainwater					
Reusing or recycling of greywater					
Use of leak proof plumbing and pressure reducing valves					
Use of water-saving fixtures e.g., low-pressure flush toilets, shower heads and sinks, dual-flush toilets etc.					
ENERGY EFFICIENT TECHNOLOGIES	1	2	3	4	5
Utilization of renewable energy sources such as solar energy					
Natural lighting/daylighting					
Use of energy-efficient fixtures such as LED bulbs, motion sensor bulbs etc.					
Use of natural ventilations instead of Air Conditioners.					
Switching off power when not in use					
WASTE MINIMIZATION TECHNOLOGIES	1	2	3	4	5
Use of bio-degradable materials					
Recycling of some waste products					
Use of re-usable materials					
Separation of waste products at the point of disposal					
On-site composting of waste					
GREEN WALLS/ROOFS TECHNOLOGIES	1	2	3	4	5
Planting of vegetation on the walls and roof top					
Planting of vegetation in containers					
Use of glass walls instead of concrete walls					
Kitchen gardening					

- Which of the following factors do you consider as significant influencers in the adoption of green building technologies?
  - Cost-effectiveness and potential savings ☐
  - Government regulations and incentives ☐
  - Environmental benefits (e.g., reduced carbon emissions, energy efficiency) ☐
  - Market demand and consumer preferences ☐
  - Improved occupant health and productivity ☐

- Availability and accessibility of green building materials
- Lack of awareness or knowledge about green building technologies

- How influential is the market demand for green buildings and sustainable practices in encouraging the adoption of green building technologies?
  - Highly influential [ ]
  - Moderately influential [ ]
  - Not influential at all [ ]