



**FRAMEWORK FOR EVALUATION OF ENERGY SUSTAINABILITY IN
UNIVERSITY STUDENTS' HOUSING IN GHANA**

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**FRAMEWORK FOR EVALUATION OF ENERGY SUSTAINABILITY IN
UNIVERSITY STUDENTS' HOUSING IN GHANA**

A thesis presented

By

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DEDICATION

This thesis is dedicated to my Wife (Mrs. Mabel Sekyere) and my children (Janice Brifaa Appau and Duvan Appau Aidoo-Koomson). Thank you for your support, prayer, and patience during this period of my study.

DECLARATION

I, Appau Williams Miller, declare that this thesis titled “Framework for Evaluation of Energy Sustainability in Evolving University Students’ Housing in Ghana” is my own work and that all sources of materials used have been duly referenced and accredited. This thesis is submitted to the Durban University of Technology in fulfilment of the requirement for the award of Doctor of Philosophy in Construction management. This thesis has not been submitted elsewhere for any degree by myself or on my behalf.

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ABSTRACT

Traditional student housing designs have not adequately addressed sustainability, leading to thermal discomfort, poor indoor air quality, and inadequate acoustic and visual comfort, resulting in negative impacts on students' health, academic performance, and social well-being. While previous research has largely centered on energy demand, power systems optimization, and usage behavior, less attention has been paid to the role of sustainable student housing design. The study aims to develop a conceptual framework to assess indoor energy sustainability in student housing in Ghana. It examines the impacts of sustainable design on energy consumption, identifies drivers and barriers to sustainable design, and evaluates behavioral control influences on energy consumption in Ghanaian student housing. Grounded in the Theory of Planned Behavior and integral sustainable design, the research adopts a pragmatist approach and uses an explanatory sequential mixed-methods design, combining quantitative and qualitative data. The sample consists of 65 student housing units across Southern and Northern Ghana, involving 340 housing managers, 224 architects, 342 student housing leaders, 65 investors, and 12 energy experts for focus group discussions. The study uses Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4 software to analyze the relationship between sustainable housing design and energy consumption. Exploratory Factor Analysis (EFA) identifies the key drivers and barriers to sustainable housing design, and the Relative Importance Index (RII) evaluates the influence of student energy behaviors on energy consumption. Key findings reveal that sustainable design decisions are influenced by building orientation, envelope design, window glazing, indoor circulation area, and floor span. However, issues like low compliance with indoor circulation space and window glazing standards negatively impact energy efficiency. Major drivers for sustainable design include high energy costs, energy-sharing mechanisms, and health and safety concerns. Barriers include high upfront investment costs, lack of knowledge, limited skills, and expensive building materials. The study develops a four-quadrant integrated framework for indoor environmental energy sustainability in student housing, providing a foundation for university management and planning institutions in Ghana. It suggests further research into social, economic, and institutional sustainability, improving compliance with the Ghana Building Code, and fostering collaboration between the Ghana Energy Commission and the Physical Planning Unit.

Keywords: Energy sustainability, Ghana, integrated building design, university students' housing

LIST OF ABBREVIATIONS

AVE	Average Variance Extracted
CFA	Common Factor Analysis
CCTV	Closed-circuit television
EFA	Exploratory Factor Analysis
FGD	Focus Group Discussion
GOF	Goodness of fit
HTMT	Heterotrait-Monotrait Ratio
IEQ	Indoor Environmental Quality requirements
HAVC	Heating Ventilation and Air-conditioning
LCC	Life Cycle Cost
LEED	Leadership in Energy and Environmental Design
PLS-SEM	Partial Least Square Structural Equation Model
PCA	Principal Component Analysis
OLS	Ordinary Least Square
RII	Relative important index
RMSEA	Root Mean Square Error of Approximation
TPB	Theory of Planned Behaviour
VBN	Value Belief Norm
VIF	Variance Inflation Factor

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LIST OF PUBLICATIONS

Journal Publications

- 1 **Appau, M.W.**, Attakora-Amaniampong, E. and Anugwo, I.C. (2024), "Indoor environmental quality and energy use intensity: an empirical post-occupancy evaluation test of on-campus university student housing in Ghana", *Property Management*, Vol. 42 No. 3, pp. 333-352. <https://doi.org/10.1108/PM-07-2023-0058>.
- 2 Attakora-Amaniampong, E., Anugwo, I.C. and **Appau, M.W.** (2024), "Relationship between indoor environmental quality and residential mobility: implications for student housing design and management in Northern Ghana", *International Journal of Building Pathology and Adaptation*, Vol. ahead-of-print No. ahead-of-print. <https://doi.org/10.1108/IJBPA-08-2023-0115>.
- 3 **Appau, M.W.**, Attakora-Amaniampong, E. and **Anugwo, I.C.** (2024). Nature of student housing in Ghana: Drivers of physical health condition effects on students living with disability (SWD) in Purpose-Built university housing. *Property Management*, Vol. 42 No. 4, pp. 523-544. <https://doi.org/10.1108/PM-08-2023-0086>.
- 4 Anugwo, I.C., **Appau, M.W.**, Simpeh, F., and Attakora-Amaniampong, E. (2025). Critical drivers of changes in energy saving behaviours in student housing in Northern Ghana. *Journal of Engineering, Design and Technology*. 1726-0531. Vol. ahead-of-print No. ahead-of-print. <https://doi.org/10.1108/JEDT-04-2024-0213>.

Conference Proceedings Publications

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2. **Appau, M.W**, Anugwo, I.C., Simpeh, F and Attakora-Amaniampong, et al. (2024) Achieving sustainability in student housing: nexus of student housing design and energy use behaviour in northern Ghana In: Laryea, S. et al. (Eds) Proceedings of the WABER SuDBE Conference, 30 to 31 July 2024, Johannesburg, South Africa 579-590

Book Chapter Publications

1. Appau, W.M., Anugwo, I.C., Okorie, V.N., and E. Attakora-Amaniampong. (2024). Smart Energy Solution Literacy Among Student Housing Investors: Perspective of Awareness and Challenges in Ghana. In: Aigbavboa, C., Thwala, W., Mojekwu, J.N., Atepor, L., Adinyira, E., Nani, G., and Bamfo-Agyei, E. (eds). *Sustainable Education and Development—Green Buildings*. PP 53-67. Published by Springer Nature Switzerland AG. ISBN 978-3-031-65369-8 (eBook). <https://doi.org/10.1007/978-3-031-65369-8>

CHAPTER ONE

1.1 Introduction

Over the last twenty years, sustainability has become a prominent topic in global discourse. The necessity for sustainability arose from the environmental impacts of industrial activities and the recognition that energy and resources are finite (Piscicelli, 2023). This awareness prompted a global response to mitigate the effects of increasing human consumption and resource demand, culminating in the establishment of the Sustainable Development Goals (SDGs). Various studies have characterized sustainability as encompassing social, economic, and environmental dimensions that govern resource utilization (Henderson & Loreau, 2023; Rinscheid et al., 2023; Guidetti & Ferrara, 2023). Additionally, some researchers have emphasized the importance of technological factors and institutional drivers of social, environmental, and economic, sustainability (Casado-Aranda et al., 2021; Ninno Muniz, 2020; Tupenaite et al., 2021). Globally, energy consumption is projected to upsurge by over 30.1% by 2040, driven by population growth and economic expansion (Newell et al., 2019; Newell & Raimi, 2020; Achuo et al., 2023). This increase is expected to be particularly pronounced in the Global South, while energy consumption in the Global North remains relatively stable (Achuo et al., 2023). Within Sub-Saharan Africa (SSA), countries continue to experience significant energy consumption due to the abundant natural resources and ongoing economic and population growth (Boukhelkhal, 2022). Furthermore, it is anticipated that lower- to middle-income countries in SSA will see a surge in energy demand over the next decade, impacting housing, industries, small to medium enterprises, and contributing to climate change challenges that lead to energy vulnerability (Murshed et al., 2022).

Recent research by Alaganthiran & Anaba (2022), Mukisa et al. (2022), and Ugwu et al. (2022) supports this perspective and highlights the likelihood of increased carbon dioxide emissions among SSA nations. Notably, Ghana and Nigeria are leading in both carbon emissions and energy consumption within the region (Qi et al., 2022). In West Africa, residential energy use constitutes approximately two-thirds of total energy demand (Powanga, 2022). In Ghana specifically, data indicate a 10.3% rise in energy consumption as of 2022, with the residential sector identified as the largest consumer of energy (Takase et al., 2022). This sector accounts for about 41% of overall energy consumption in Ghana (Takase et al., 2022), underscoring a pressing need for research focused on energy sustainability within residential contexts in the country. University campuses are significant consumers of energy, comparable to commercial properties. They play a crucial role in fostering sustainable human environments and promoting social development through academic pursuits and research initiatives (Eromobor, Das, & Emuze, 2020; Sanni-anibire & Hassanain, 2016; Hassanain, 2008). As centers for knowledge generation, universities are also integral to enhancing the sustainability of built environments by implementing various sustainability programs such as outreach initiatives and environmental conservation efforts (Genta et al., 2022; Hidalgo-González et al., 2022; Suhaili & Ismail, 2023).

However, student housing—an essential aspect of university life—has seen fewer initiatives aimed at improving energy sustainability practices (Simpeh & Akinlolu, 2021). This gap can be attributed to deficiencies in design assessment programs, construction monitoring protocols, and post-occupancy evaluations concerning building control systems (McCartney & Rosenvasser, 2022; Attakora-Amaniampong et al., 2022). Student housing consumes substantial amounts of energy for various activities including cooking, lighting, ironing, bathing, heating, ventilation, and air conditioning. Implementing effective energy sustainability measures could significantly reduce

overall energy consumption and operational costs while mitigating climate change impacts and enhancing building sustainability (Oyedepo et al., 2019). Demand for student housing continues to rise due to increasing enrollment rates in public universities—often exceeding available accommodations—private sector involvement in off-campus student housing has become more prominent in developing countries (Attakora-Amaniampong et al., 2020; French et al., 2018). Addressing energy sustainability within student housing emerges as a strategic approach to counteract potential future vulnerabilities related to energy supply within this sector. While some scholars have focused on outdoor environmental sustainability within university campuses (Gregory, 2020; Olanipekun & Iyiola, 2020), others modeling energy sustainability have primarily concentrated on its economic aspects—such as energy demand-supply dynamics and cost fairness—neglecting crucial factors like building design elements and occupant behaviors that influence energy efficiency.

The indoor environmental conditions that affect students' comfort and health remain underexplored. In Ghanaian scholarship on energy issues, there has been a predominant focus on investment strategies related to demand-supply dynamics and marketing within an economic sustainability framework (Dramani et al., 2022; Kutortse, 2022; Gyimah et al., 2022; Ohene et al., 2022; Oke et al., 2022). Research addressing residential energy efficiency aimed at reducing consumption is limited (Ohene et al., 2022; Anzagira et al., 2022), with few studies exploring residential sustainability through green building concepts facing challenges related to implementation and certification processes (Opoku et al., 2022; Anzagira et al., 2022; Debrah et al., 2022). Furthermore, investigations into environmental sustainability have revealed a direct correlation between indoor conditions and student health outcomes (Mawonde & Togo, 2019; Ullah et al., 2021; Tong et al., 2021), while Olanrewaju et al. (2019) established links between

students' academic performance and the indoor environments. Liu & Wang (2022) found that room temperature satisfaction and visual comfort were influenced by building geometry. Nonetheless, aspects of student housing that impact energy sustainability remain largely unexamined. Consequently, this study will concentrate on the indoor environmental factors related to energy sustainability within student housing in Ghana.

1.2 Changing nature of university student housing: cross-border perspective

In recent decades, student housing has undergone significant transformations in design, construction, operation, and occupancy, largely driven by increased enrollment rates worldwide (Amoah et al., 2023; Attakora-Amaniampong et al., 2021). In developed countries, the predominant model has been on-campus housing. Conversely, in developing nations, there has been a notable shift towards off-campus housing solutions. This transition is ascribed to factors such as rising enrollment numbers, inadequate availability of on-campus accommodations, and a growing demand for privacy and comfort among students. Research on student housing in Africa has primarily focused on South Africa, Nigeria, and Ghana (Gbadegesin et al., 2021; Attakora-Amaniampong et al., 2021; Mbazor, 2021; Simpeh & Akinlolu, 2019).

However, there is a scarcity of studies examining the nature of student housing in urban and peri-urban universities in countries like Tanzania, Zambia, Senegal, and Cameroon, where the private sector predominantly leads these initiatives (Mtani et al., 2019; Magambo et al., 2020; Tumaini, 2022). In South Africa, the student housing model has shifted from traditional on-campus arrangements to shared living spaces (Xulu-Gama, 2019). Recently, there has been a transition towards Purpose-Built Student Hostels (PBSH), which involve repurposing single-family homes for student accommodation (Simpeh & Shakantu, 2020; Gbadegesin et al., 2021). PBSH is characterized by its all-inclusive amenities such as laundry services, shops, study rooms, and gyms

(Gregory, 2020). This shift has facilitated public-private partnerships and franchises aimed at developing large commercial student housing complexes (Mugume & Luescher, 2015; Xulu-Gama, 2019). Additionally, modern facilities now incorporate advanced security measures like CCTV systems and fire safety installations (Adisa et al., 2019; Plessis et al., 2021). Some universities in South Africa have also implemented residence education programs to promote sustainable living among students (Gregory, 2020; Yildiz & Koçyiğit, 2020; Mahdavi et al., 2021).

Similar transformations have been observed in Nigeria's student housing sector (Olanipekun & Iyiola, 2020). Here, the demand for on-campus accommodations has surged due to The accessibility and maintenance advantages (Mbazor, 2021). The emergence of single-room occupancy units equipped with internet access and amenities such as mini-markets and clinics is becoming increasingly common in on-campus housing (Adama et al., 2018). However, off-campus options are facing challenges related to high energy costs, inadequate maintenance, crime rates, and noise issues (Gbadegesin et al., 2021), leading to extensive research on student satisfaction regarding housing conditions in Nigerian tertiary institutions. In Ghana, student housing was traditionally based solely on-campus until about twenty-five years ago. The mid-2000s saw a significant rise in student enrollments which created an urgent need for more on-campus accommodations. This led to the introduction of policies allowing students to reside outside campus facilities (Attakora-Amaniampong et al., 2021), thereby fostering the growth of the off-campus housing market. Initially characterized by compound houses and multi-family units, off-campus student housing has increasingly evolved into purpose-built hostels. Many universities are now engaging in public-private partnerships to enhance the on-campus housing capabilities (Revington & August, 2020). Contemporary student residential halls are being designed with private kitchens, common areas for socializing and studying, cooling systems, libraries, and

internet access. Given these developments, assessing environmental energy sustainability within university housing is becoming increasingly crucial.

1.3 Problem statement

Globally, the built environment is responsible for a substantial portion of energy consumption, encompassing energy utilized during various stages such as construction, operation, refurbishment, and demolition (Saradara et al., 2023; Olanrewaju et al., 2019). Notably, the operational phase alone accounts for approximately 40% of total energy consumption worldwide (Olanrewaju et al., 2019). In developing countries, ensuring energy sustainability in student housing has emerged as a pressing concern for both researchers and practitioners (Simpeh & Akinlolu, 2021; Sakah et al., 2019). In Ghana, the pursuit of energy sustainability within student accommodations faces several challenges, including high energy costs, a growing student population, non-compliance with building regulations, and general indiscipline in energy usage—issues that are also prevalent in many Sub-Saharan African nations (Ibrahim et al., 2023).

The factors influencing adherence to design standards, construction materials, and students' attitudes toward energy consumption remain largely unexplored (Olanipekun & Iyiola, 2020; Mbazor, 2021). The cumulative effects of these challenges can lead to discomfort among students, diminished academic performance, health issues, and social disorganization. Conversely, studies in other regions have highlighted the significant impact of indoor energy sustainability on students' learning outcomes, as well as the physical and mental well-being (Lee et al., 2015; Wiley et al., 2017; Lee et al., 2022; Liu & Wang, 2022). Over the past five decades, research on indoor environmental sustainability has predominantly emerged from Europe, Asia, Australia, and the United States (Barmeparesos et al., 2019; Yadegaridehkordi & Nilashi, 2022; Hopkins, 2022). These studies have developed indoor energy sustainability models tailored to local climatic

conditions. For example, research in Greece has examined indoor environmental conditions concerning weather variables such as temperature and humidity in student dormitories (Barmmparesos et al., 2019).

In Denmark, Austria, and Australia, investigations have focused on building geometry and outdoor environments (Majd et al., 2019; Mahdavi et al., 2021). Meanwhile, studies in Turkey and neighboring countries have looked into building orientation and retrofitting strategies (Buldur et al., 2020; Yildiz & Koçyiğit, 2020). Research conducted in China has emphasized energy demand and supply dynamics alongside cost considerations and environmental layout (Liu & Ren, 2020; Chen & Gou, 2022). In Malaysia and Singapore, studies have concentrated on energy awareness and conservation efforts as well as indoor air quality concerns (Abualreja et al., 2020; Heydarian et al., 2020; Tong et al., 2021; Ullah et al., 2021). Recent research from Europe and Asia has advocated for assessing building designs as critical determinants of environmental energy sustainability in residential structures (Qian et al., 2023; Alqahtani et al., 2023; Ibrahim et al., 2023). While this is a commendable initiative, many developing countries have yet to adopt similar approaches.

A scientometric review by Simpeh and Akinlolu (2021) revealed significant gaps in research concerning sustainable student housing—particularly regarding indoor energy sustainability. In Africa, Nigeria and South Africa have conducted a limited number of studies focused on indoor energy sustainability in student housing. However, these investigations primarily center on energy demand-supply dynamics and the optimization of power systems alongside usage behaviors (Olanrewaju et al., 2019; Mawonde & Togo, 2019; Olanipekun & Iyiola, 2020; Mbazor, 2021). Such studies often rely on data from selected university buildings using Building Information Modelling techniques. Consequently, the influence of building design on energy sustainability

within student housing remains inadequately addressed. Recent research on student housing sustainability in West Africa has tended to emphasize post-occupancy evaluations of facilities along with aspects like all-inclusiveness and safety—elements that fit neatly within the framework of environmental sustainability (Appau et al., 2024; Simpeh & Akinlolu, 2021).

In Ghana, the increase in university student numbers and the emergence of multi-university campuses have placed a significant change in student housing supply— with increasing pressure on energy consumption (Appau et al., 2024). Despite that, studies have shown that there is a high energy use intensity of 75.9 kWh/m²/month in Ghanaian student housing market, which is worrisome (Attakora-Amaniampong et al., 2023; Appau et al., 2024). This has created indoor environmental challenges, ill-health, and energy cost to investors. Notwithstanding the rising penetration of smart energy devices and sustainable student housing, energy consumption remains high (Appau et al., 2024). This calls for a study to develop a model for sustainable student housing design in Ghana.

Few scholars (Appau et al., 2024; Amoah et al., 2023; Avogo et al., 2022; and Simpeh and Shakantu, 2019) have made some attempts to evaluate the nature of student housing and indoor environmental energy, however, there exists a notable gap concerning the specific energy-related dimensions that require further exploration. Issues related to student housing design—including drivers and barriers to effective implementation—along with students' perceptions of indoor building control systems in relation to energy sustainability have been largely overlooked in existing literature.

1.4 Aim and objectives of the Study

The aim of this study is to develop conceptual model on critical factors influencing the indoor environmental energy sustainability of student housing in Ghana. In order to achieve the aim of this study, the following specific research objectives and questions were formulated.

1. To examine building design requirements and the influences on indoor environmental energy sustainability in student housing in Ghana
2. To identify the drivers of adopting sustainable student housing design in Ghana
3. To assess the barriers to adopting sustainable student housing design in Ghana
4. To assess students' behavioral control of student housing design systems towards indoor environmental energy sustainability in Ghanaian student housing
5. To develop a conceptual sustainable design framework for indoor environmental sustainability in student housing

1.5 Research Questions

- 1a. What are the critical design requirements in student housing for indoor environmental energy sustainability in Ghana?*
- 1b. How does sustainable building design influence indoor environmental energy sustainability in student housing in Ghana?*
- 2a. What are the key factors of adaptation of sustainable student housing design and implementation in Ghana?*
- 3a. What critical barriers affect the adaptation of indoor environmental energy sustainability designs among student housing in Ghana?*
- 4a. What student attitude of building control systems influences indoor environmental energy sustainability in Ghana?*

4b. What is the relationship between students' interactions with building controls and The effects on energy consumption and the indoor environment?

1.6 Significance of the study

The necessity for energy sustainability across various economic sectors is widely acknowledged; however, the contributions of energy sustainability research within student housing—an integral segment of commercial real estate—remain underexplored. This study is framed within the context of Sustainable Development Goal (SDG) 7, which aimed to ensure universal access to reliable, affordable, modern, and sustainable energy. By focusing on indoor environmental energy sustainability in university student housing in Ghana, this research provided a comprehensive guideline for its implementation. Additionally, it aligns with SDG 12, which emphasizes sustainable production patterns and consumption by investigating the relationship between building control systems and student behavior. Furthermore, the study seeks to address SDG 11, which promotes smart and sustainable urbanization by concentrating on the barriers and drivers of adopting sustainable student housing designs. Upon completion, the findings would pave the way for new policy recommendations that guide student housing investors regarding the adoption of sustainable indoor energy appliances, smart energy operational cycles, and consumption practices.

This research also evaluated the capacity of university housing management, contractors, and private investors to adapt the energy usage strategies effectively. Theoretically, this study contributes to the body of knowledge and academic discussions on sustainable buildings in several significant ways. It represents a pioneering effort to develop a framework for indoor energy sustainability specifically tailored to student housing, contrasting with previous studies that have predominantly focused on residential and industrial housing in the Global North. Moreover, it establishes a theoretical foundation for formulating energy requirements for university student

housing across Africa, particularly in Sub-Saharan countries where there is substantial energy consumption and a high demand for student accommodations. By situating this research within integrated design theories as well as socio-environmental and psycho-environmental frameworks, it aims to advance the discourse on energy sustainability in the built environment, particularly concerning student housing.

Practically, the operation of buildings would be enhanced as students are guided in The actions to meet The needs while achieving potential energy savings. This approach will provide greater certainty regarding building performance and energy consumption. Additionally, the study aimed to contribute knowledge that would assist in reducing carbon emissions as it assessed compliance with building design standards between older and modern structures. Understanding the drivers and barriers identified in this research will equip building owners and architects with insights into essential factors that promote the adoption of sustainable student housing designs while addressing challenges related to the implementation.

1.7 Methodology

The study used the Explanatory Sequential Mixed Research Method grounded in Pragmatist Philosophical Thinking. This approach allows for qualitative findings to elucidate quantitative research results. A survey was conducted to gather primary data from key stakeholders, including architects, contractors, student housing managers, and students, focusing on indoor environmental energy sustainability. The sample consists of on-campus public and private student housing, specifically targeting 14 public universities located in both the Northern and Southern regions of Ghana. To evaluate the requirements for sustainable student housing design, quantitative methods were utilized to ascertain these criteria. The Partial Least Square Structural Equation Model (PLS-SEM) was employed to analyze the impact of sustainable housing design requirements on energy

consumption within Ghana. For the second objective, Exploratory Factor Analysis (EFA) was used to identify the key drivers of sustainable student housing design. Similarly, EFA was used to assess the barriers to implementing sustainable student housing designs as part of the third objective.

The fourth objective leveraged on the use of Relative Importance Index (RII) alongside PLS-SEM to investigate how student behavioral control contributes to indoor environmental energy sustainability. Additionally, focus group discussions was held with energy experts to gather insights on the requirements of sustainable student housing design and its barriers in Ghana. Ultimately, the findings from objectives one through four informed the development of a framework aimed at enhancing indoor energy sustainability in on-campus student housing across Ghana. Detailed methodology is elaborated in Chapter Five of the study.

1.8 Scope of the study

The scope of the study is delineated into two broad categories: conceptual scope and geographical scope. The conceptual scope focuses on the indoor environmental energy sustainability of student housing in Ghana. Environmental sustainability is posited as the foremost framework that underpins other sustainability initiatives. Within this framework, the study specifically examine factors such as building design, the drivers and barriers associated with that design, and the behavioral patterns of students regarding energy use. In terms of geographical scope, the research concentrates on on-campus student housing across public universities in Ghana. This focus is essential, as it allows for a detailed exploration of how indoor environmental factors affect energy sustainability within the unique context of Ghanaian universities. By concentrating on these specific dimensions, the study aims to provide valuable insights into enhancing energy efficiency and overall sustainability in student accommodations, addressing critical challenges faced in the sector. This approach aligns with broader discussions on sustainable architecture and energy

conservation, emphasizing the importance of integrating effective design principles and understanding user behavior to foster a more sustainable living environment for students.

1.10 organization of chapters of the study

The study was organized into ten chapters. Chapter one presents the background of the study, problem statement, research aims and objectives, scope, methodology, and significance of the study. the second chapter reviews literature on sustainability concepts. Chapter three reviews the theories of the study. The fourth chapter presents the conceptual framework of the study. Research methodology forms the fifth chapter. The sixth chapter describes the survey results of the study. Results on focus group discussions was presented in chapter seven. Chapter eight discusses the research findings. Chapter 9 presents the framework governing the study. The final chapter presents the research contributions, conclusions, and recommendations.

CHAPTER TWO

CONCEPTS AND GAPS IN BUILDING ENERGY SUSTAINABILITY

2.1 Introduction

The chapter reviews literature concerning building energy sustainability, with a particular focus on several key areas. It begins by exploring building design requirements and the usage of materials as fundamental drivers of environmental sustainability. Effective building design is crucial for minimizing energy consumption and maximizing resource efficiency, which are essential components of sustainable architecture. The chapter highlights various strategies, such as passive and active sustainable design techniques, which include optimizing natural light, utilizing renewable energy sources, and selecting environmentally friendly materials. Furthermore, the chapter examines the drivers and barriers associated with sustainable building design. Understanding these factors is vital for implementing effective sustainability measures in student housing. The literature indicates that while there are numerous incentives for adopting sustainable practices—such as enhanced residents well-being and cost savings—challenges remain. These challenges include regulatory hurdles, financial constraints, and resistance to change among stakeholders. . The final aspect of the review focuses on behavioral control regarding indoor energy systems. This section underscores how occupants' behaviors significantly influence energy consumption patterns within buildings. Research has shown that when students are educated about energy-saving practices and provided with control over the indoor environments—such as lighting and temperature settings—they tend to engage in more sustainable behaviors.

The chapter concludes by emphasizing the interconnectedness of building design, material usage, and occupant behavior in achieving indoor environmental energy sustainability. By synthesizing these elements, the chapter sets the stage for understanding how effective strategies can be

developed to enhance energy sustainability in student housing contexts. It also identifies gaps in existing research that this study seeks to fill, particularly in relation to the unique challenges faced by developing countries like Ghana.

2.2 Definition of concepts of sustainability

The concept of sustainability encompasses a wide range of interpretations influenced by various disciplines and perspectives. According to Zhong et al. (2022), sustainability is fundamentally about supporting the basic needs of individuals. In contrast, Fallah Shayan et al. (2022) broadens this definition to include environmental, economic, and social responsibilities. Ali et al. (2022) presents a different viewpoint, defining sustainability as the interconnectedness of environmental and human activities, taking into account the needs of present, past, and future generations at local, regional, and national levels. From these definitions, it can be inferred that sustainability aims to protect the environment while ensuring a high quality of life across all levels of development. This aligns with the Brundtland Commission's definition from 1987, which explains sustainable development as meeting the needs and aspirations of the present generation without compromising the needs and abilities of future generations. Sustainability has been conceptualized around three key overlapping principles that promote a balanced approach to social, economic, and environmental well-being (Hashim et al., 2023).

Scholars have noted that climate change and heightened environmental awareness have positioned sustainability at the forefront of housing discussions, leading to the adoption of building designs and construction practices that support sustainable development goals (Asfour, 2023; Hidalgo Zambrano et al., 2023; Kousar et al., 2022). Cheng et al. (2022) and Zhong et al. (2022) argue that building designs can have minimal adverse effects on both natural and built environments. Importantly, sustainability has been shown to facilitate efficient resource use and enhance quality

of life. Additional research indicates that sustainability fosters a more integrated approach to environmental housing solutions, social, and economic. In other aspects of sustainable buildings, various studies categorize the concept into areas such as energy efficiency, pollution prevention, resource efficiency, and environmental harmonization (Cheng et al., 2022; Koranteng et al., 2022; Mujan et al., 2019). However, ambiguity remains regarding sustainability indicators within the housing sector. Given this context, this study primarily focused on the environmental aspects of sustainability.

2.3 An Overview on Concept of Environmental sustainability

Environmental sustainability is a crucial component of the broader sustainability framework. Environmental sustainability is defined as the resilience and balance that enable human societies to meet the needs while safeguarding the environment (Morelli, 2013). Over the years, scholars have identified several challenges to achieving environmental sustainability, including energy efficiency, water pollution, climate change, and reliance on fossil fuels. Ionescu (2021) supports this perspective, emphasizing that energy efficiency and climate change are particularly prominent issues in current research discussions (Mahi et al., 2021). Mahi et al. (2021) further argues that environmental energy sustainability is vital as the world moves toward zero-energy goals. However, whether economies will proactively plan for an equitable transition to zero-energy sustainability while considering environmental factors remains a topic of debate. Within this context, student housing plays a significant role in promoting environmentally friendly energy sustainability. Indicators of environmental sustainability in housing can be categorized into several key areas: indoor environmental quality, energy-efficient measures, energy consumption during construction and use, renewable energy utilization, the sustainability of building materials, and visual comfort (Haupt & Hellweg, 2019; Muj).

Other scholars expand on this by including building design, orientation, and layout as essential components of environmental energy sustainability (Munaro et al., 2020; Carvalho et al., 2019). Rezaei et al. (2019) highlight that the design stage of buildings is critical for mitigating the adverse impacts on the environment. Additionally, Vita et al. (2019) emphasize that residents' environmental awareness and the implementation of smart energy controls are significant factors contributing to energy efficiency in buildings. The literature indicates that sustainable student housing can effectively address these challenges by integrating advanced design principles and technologies. For instance, incorporating smart technologies such as smart thermostats and HVAC systems can optimize energy consumption based on occupancy patterns (Doma et al., 2024). Furthermore, the adoption of renewable energy sources like solar panels can significantly reduce reliance on conventional power grids while decreasing carbon emissions (Osman et al., 2024).

In summary, while various challenges to environmental sustainability exist within the housing sector, student housing presents a unique opportunity to implement innovative solutions that promote energy efficiency and minimize environmental impact. This study focuses on the environmental aspects of sustainability in student housing, aiming to explore how these indicators can be effectively integrated into contemporary housing designs.

Empirical arguments on critical environmental energy sustainability indicators are discussed below.

2.3.1 Material usage effects on environmental energy sustainability

Material selection in building construction significantly influences energy performance, with numerous studies demonstrating a direct relationship between the choice of materials and overall building efficiency (Koranteng et al., 2022; Peng et al., 2019). Empirical research has shown that utilizing local materials can enhance environmental sustainability. For instance, Ndlangamandla

& Combrinck (2020) conducted a situational analysis and systematic review to explore the contributions of environmental energy sustainability in the Kingdom of Eswatini. The findings indicated that inefficient energy usage, poor material selection, inadequate construction oversight, and lack of planning by building authorities are major challenges to environmental sustainability in the region.

Similarly, Ikediashi et al. (2020) performed a post-occupancy assessment of university buildings through quantitative questionnaires. The study found that inadequate lighting, quality of building materials, and insufficient illumination significantly affect energy consumption. Moreover, the absence of post-occupancy evaluations among stakeholders and residents' hampers efforts toward achieving energy sustainability. In another study, Peng et al. (2019) examined the implications of building materials on energy flows in residential buildings in China. They found that high-quality materials not only improve energy consumption, but also enhance indoor residential thermal comfort in context. Other scholars such as Koranteng et al. (2022) further explored the potential of green roofs in promoting environmental energy sustainability in Kumasi, Ghana, using a simulation-based analysis of forty-two years of weather data. The results indicated that incorporating green roofs into building designs led to lower indoor temperatures and reduced energy usage.

Taking insights from Jegede & Taki (2022), who developed a comprehensive model assessing indigenous building materials' impact on energy sustainability in Abuja, Nigeria, it was observed that using local materials offers significant advantages. These indigenous materials contribute to lower annual operative temperatures and reduced thermal adaptation needs, particularly for ground floors, roofs, and external walls. However, they also noted that reliance on mechanical cooling systems can lead to excessive energy consumption within these buildings. Overall, these findings

underscore the important function that material usage plays in enhancing energy performance and promoting sustainability within the built environment. By selecting appropriate materials and integrating innovative design strategies, it is possible to attain significant fall in energy consumption while improving occupants' comfort and well-being.

2.3.2 Building design contribution on environmental energy sustainability

Discussions on the design implications of buildings on sustainability have garnered attention among scholars, with diverse perspectives on the drivers of these designs. Several studies have highlighted the relationship between design aspects such as functional design, equipment design, and system design, and the impact on building sustainability (Chen et al., 2020; Nwodo & Anumba, 2019). Chen et al. (2020) argue that functional design has a significant positive effect on energy sustainability in residential buildings, a view also supported by Nwodo and Anumba (2019). Functional designs are classified into active and passive designs, both of which contribute to energy sustainability. Contextual debates, however, have emerged regarding the critical role of building orientation, the building envelope, and internal layout in achieving functionality (Wang & Zhang, 2021; Bachrun et al., 2020; Luo et al., 2019). While some studies emphasize the importance of equipment and system design in energy sustainability, Bachrun et al. (2020) challenge this notion, arguing that functional design elements are critical for energy performance. Wang & Zhang (2021) also consider systems and equipment design as predictors of functional design's role in sustainability.

These debates have resulted in different methodologies for assessing energy sustainability through design. Many empirical studies, however, tend to overlook student housing designs. For example, Kamal (2013) used interviews, observations, and environmental indicators to examine how Leadership in Energy and Environmental Design (LEED) impacts affordable housing in Saudi

Arabia, finding that LEED promotes energy sustainability. However, Kamal's study did not address inefficiencies in energy use during the post-construction phase. Similarly, Thomsen et al. (2013) conducted qualitative interviews with users in six buildings to assess satisfaction with energy sustainability, reporting that while users were generally satisfied with the new energy-efficient designs, dissatisfaction arose from the failure to adequately address thermal comfort. Other studies suggest that post-design solutions and adaptations do not always guarantee energy sustainability.

Chel & Kaushik (2018) identified four key drivers of energy efficiency in buildings, emphasizing the need to assess building design during the construction phase, in addition to considering materials, energy technologies, and renewable energy applications. Lu et al. (2017) reviewed 400 articles on the application of Building Information Modeling (BIM) in green buildings in China, concluding that assessing design at the construction phase is vital for long-term energy sustainability. In the context of university buildings, Liu & Ren (2020) conducted a systematic review of energy sustainability on Chinese campuses, finding that functional design, system design, construction strategies, and equipment strategies are optional yet essential for energy efficiency. A critical issue identified in this study is that space design and division should be considered early in architectural planning. However, Chen et al. (2020) offers a contrasting view, suggesting that the focus on energy sustainability has shifted from construction to operational and technological upgrades during building management. Chen's study highlights that the behavior of residents in relation to lighting, ventilation, air conditioning, and visual comfort significantly impacts energy performance.

Several other studies also emphasize the role of building design in energy sustainability. Nimlyat et al. (2022) applied structural equation modeling to explore how environmental sustainability

influences comfort in Nigerian residential buildings, revealing that building orientation plays a significant role in thermal comfort. This observation is consistent with studies in Asia, where the relationship between design and comfort has also been confirmed (Li & Liu, 2020; Malik & Bardhan, 2022). Sari et al. (2022) assessed energy sustainability drivers in Indonesian residential buildings, finding that warm thermal comfort is a common issue. Thomsen et al. (2013) similarly highlighted that inadequate air circulation, poor access to natural light, and frequent window closures contribute to elevated indoor temperatures and humidity, reducing the overall comfort in buildings. Delzendeh et al. (2017) argued that the role of resident behavior is often overlooked in energy studies, recommending future research on the influence of interior design and layout on energy performance.

In Ghana, Agyekum et al. (2021) analyzed energy sustainability in certified buildings, finding that the space layout contributes to high levels of daylight and artificial lighting. However, the study neglected outdoor spaces. Hassanain et al. (2021) assessed the design quality of student housing, reporting that building positioning affects the amount of natural daylight received. Yu et al. (2019) explored the effects of passive and active design strategies in solar residential buildings, suggesting that while both can be effective, an integrated approach is needed to balance architectural design and occupant comfort. Sun et al. (2018) examined the cost implications of building design on energy performance in Southern Asia, revealing that while retrofitting can improve energy efficiency, certain strategies, such as efficient air conditioning and lighting, are more cost-effective.

The need for passive design strategies has been further supported by Kürüm Varolgüneş (2019), who studied cold climate regions and found that while residents were generally satisfied with thermal and visual comfort, mechanical systems were necessary to enhance indoor performance.

However, the cost and health impacts of mechanical installations are critical considerations. Laloui et al. (2022) examined the effects of voids in building designs, finding that horizontal voids improve energy sustainability through better ventilation, although the building's location and wind direction are crucial factors. In contrast, Abdollahzadeh et al. (2022) studied the correlation between student dormitory design and energy sustainability, finding that window size, location, and other features such as reflectors and vents contribute significantly to energy efficiency.

Studies in Finland also highlight the role of technological and material improvements in building design. Kaasalainen et al. (2020) found that window size and positioning, along with shading, are critical to achieving energy sustainability. Kosonen & Keskisaari (2020) and Hirvonen et al. (2020) emphasized the importance of retrofitting designs in the Nordic context. Similar conclusions were drawn by Bughio et al. (2021) in Pakistan, where thermal insulation and high-efficiency windows were shown to enhance energy sustainability. In South Africa, Eromobor et al. (2021) identified drivers such as indoor temperature, window size, and nature of lighting as major influences on energy consumption in university buildings. More recent studies, such as Afful et al. (2023), categorized the factors contributing to energy sustainability into environmental, cultural, and economic enablers.

Finally, Jung et al. (2021) assessed seasonal variations in energy sustainability in Dubai, finding that residential designs that cater to thermal comfort during summer and indoor quality during winter are essential. In contrast, Kamaruzzaman & Azmal (2019) identified artificial lighting and noise as major sources of dissatisfaction, while ventilation and health-related factors were considered crucial for energy sustainability. Similarly, Chan et al. (2008) reported that residents in densely populated urban buildings in Hong Kong were able to adapt to lower levels of daylight and higher indoor temperatures, though noise remained a significant issue affecting The daily lives.

2.4 Critical drivers of building design requirements

Scholars consistently highlight the importance of building orientation, design complexity, building envelopes, window glazing, and indoor circulation space in influencing energy consumption. Gupta & Deb (2023) and Homod et al. (2021) identify these factors as critical in shaping energy efficiency, supported by Li et al.'s (2020) study on 549 residential buildings in China, where orientation, floor area ratio, and building height were key determinants. Liu and Wang (2022) further emphasize building orientation's impact on energy consumption, revealing it as more influential than building envelope performance. Additionally, Homod et al. (2021) note that vernacular buildings in Iraq contribute significantly to energy savings, reaching up to 47.8%.

Gupta & Deb (2023) advocate for optimizing the design of building envelopes, particularly in tropical regions, where strategies like insulation, window-to-wall ratios (WWR), and shading systems are vital for reducing energy usage. Marouane et al. (2023) also confirm the importance of building envelope optimization in North African countries, finding reductions in energy consumption between 31% and 56%. Similarly, Mostafavi et al. (2021) found that enhancing building envelopes can cut energy consumption by as much as 78.9%.

Studies also explore the association between energy efficiency, building height, and orientation. Mangan et al. (2021) found that building height had a greater effect on energy and cost efficiency than orientation in Istanbul. Aboelata (2021) showed that green roofs reduce cooling energy significantly, depending on building height, with taller buildings benefiting less. Hu & Xiao (2020) confirm these findings, noting that single-story residences in Hong Kong have the highest potential for energy flexibility.

The role of indoor circulation and design on energy efficiency has also been examined. Alghamdi et al. (2022) report that adjusting cooling set-point temperatures in indoor circulation systems

reduced indoor temperatures by 20% and energy consumption by 41% in Australian educational buildings. Uddin et al. (2022) similarly found that improving interior designs enhanced energy performance by 14.9%. Additionally, Ozarisoy & Altan (2022) highlight the impact of indoor circulation on heating consumption in South-Eastern Europe, particularly on weekends.

Window glazing is another critical factor. Cherier et al. (2024) found that glazing type, rather than size or orientation, was the dominant factor in energy savings in Algeria, with Low-E glazing models offering the most savings. De Luca et al. (2022) also point out that static shading glazing reduced energy use by 29.1% while controlling visual discomfort in Estonia. Other studies, such as Liu et al. (2023) and Mohammed et al. (2022), underscore the effectiveness of shading devices in reducing cooling and lighting loads, enhancing energy efficiency.

Finally, indoor floor area and building shape also significantly impact energy sustainability. Chen et al. (2020) emphasizes that optimizing building size, shape, and energy-efficient equipment can substantially reduce energy demand. Al-Saggaf et al. (2020) further suggest that window glazing, shape complexity, and orientation characteristics play crucial roles in influencing cooling loads in hot climates. These findings highlight the multifaceted nature of energy consumption in buildings, underscoring the need for integrated approaches to design for energy sustainability.

2.5 Drivers of sustainable residential building design and construction implementation.

The necessity for adopting sustainable buildings has been driven by various environmental, social, technological, and economic factors. Scholars have identified different drivers of sustainable building practices that vary by country context, although many of these drivers are globally relevant. For example, Santamouris and Vasilakopoulou (2021) highlight excessive resource use, climate change, overpopulation, and intensive urbanization as key socio-economic drivers of sustainable building design. Kanters (2020) assessed the perceived drivers of sustainable design

adaptation among engineers, contractors, and architects across several European countries, including Italy, Spain, Germany, Belgium, the Netherlands, and France. This study categorized the drivers into social, economic, technical, environmental, and legal factors, noting that legal drivers were the weakest among them. Ghasemian et al. (2020) conducted a global review that quantified drivers of sustainable building design as political, economic, technological, and social. They found climate change and population growth to be significant socio-environmental drivers while identifying client behavior and financial investments in energy infrastructure as economic-related factors.

Windapo (2014) identified legislation, competitive advantage, and rising energy costs as critical drivers for adapting sustainable building practices. Although ecological drivers were less frequently selected in the study, it was noted that increasing energy costs would perpetuate the demand for sustainable buildings. Khan et al. (2022) found that policy demand, environmental concerns, social factors, and temporal aspects significantly influence sustainable building practices. Among these drivers, social factors were particularly emphasized. Tokbolat et al. (2020) reported that environmental challenges are vital for enhancing sustainability in building practices. The findings showed high significant levels of economic drivers, followed closely by social influence. Moreso, De la Cruz-Lovera et al. (2017) classified the drivers into technological, social, and economic categories. Similarly, Pan and Pan (2021) identified legislative, cultural, economic, supply chain, and geographical drivers as influential in promoting sustainability in buildings. In summary, while various studies have highlighted a range of drivers affecting sustainable building design across different contexts, common themes emerge regarding the importance of economic factors alongside social and environmental considerations. The ongoing discourse emphasizes the

need for a comprehensive understanding of these drivers to effectively implement sustainable building practices globally.

2.5.1 Environmental drivers affecting sustainable building design

The demand for energy-efficient structures has become increasingly critical, prompting designers to focus on various architectural elements such as building shape, cooling systems, orientation, glazing, and roof insulation (Pacheco et al., 2012; Ihm & Krarti, 2012). These design features are recognized as cost-effective approaches to minimize energy consumption in residential buildings. Bakar et al. (2015) identified several operational factors influencing energy consumption, including building materials, weather conditions, occupancy levels, and HVAC systems. Chenari et al. (2016) further emphasized the significance of air-conditioning, ventilation, and heating systems in enhancing energy efficiency, noting that ventilation is particularly vital for maintaining indoor air quality and comfort while promoting energy savings. However, the study also highlighted that occupant behavior poses a significant threat to energy sustainability. Liu et al. (2021) found a correlation between occupants' energy-saving behaviors and productivity and health outcomes. They noted that ventilation is closely linked to building control systems and is influenced by both indoor and outdoor conditions. Numerous studies support the assertion that building orientation, design complexity, building envelopes, window glazing measurements, and indoor circulation spaces have substantial impacts on energy consumption (Gupta & Deb, 2023; Homod et al., 2021).

According to Li et al. (2020), key determinants such as building orientation and floor area ratio negatively affect energy consumption. Liu & Wang (2022) on the other hand found that the surrounding environment had positive significant effects on energy consumption than building envelope performance. The study further noted that optimizing the building envelope can lead to

substantial reductions in annual energy loads of about 47%. Similarly, Homod et al. (2021) reported that vernacular buildings could achieve up to 47.8% in energy savings by focusing on thermal comfort through optimized building envelopes. Mostafavi et al. (2021) found that enhancing the building envelope could reduce energy consumption by 79% compared to relying solely on natural ventilation or optimizing room layouts. Gupta and Deb (2023) emphasized the importance of insulating building envelopes in low-energy buildings located in tropical regions.

In North Africa, Marouane et al. (2023) assessed various design standards and found that optimizing factors such as window shading and HVAC efficiency could lower energy consumption by 31%–56%. However, they noted variability in envelope requirements across the subregion. Other studies have explored specific aspects of building envelopes, such as window glazing's impact on energy sustainability. Cherier et al. (2024) found that glazing type significantly affects energy savings in Algeria's hot semi-arid climate. The simulations revealed that low-emissivity (Low-E) glazing was particularly effective in achieving energy efficiency. In summary, the literature underscores the critical role of various design elements—including material selection and building orientation—in promoting energy efficiency within residential buildings. By integrating these elements into sustainable design practices, it will seek to significantly reduce energy consumption while enhancing end-user's comfort and overall sustainability outcomes.

2.5.2 Social drivers influencing sustainable indoor energy practices

Social drivers play a substantial role that impacts sustainable indoor energy practices in housing, often exhibiting an indirect relationship with other drivers. Empirical studies have substantiated this claim. For instance, Nikou (2019) utilized Structural Equation Modeling (SEM) to assess the driving forces behind smart energy adaptation. The findings indicated that perceived technology use, compatibility, and perceived usefulness were pivotal factors, while perceived costs negatively

impacted intentions to adopt smart energy technologies. Li et al. (2019) conducted semi-structured interviews and online surveys, revealing that client demand and social awareness are critical in promoting sustainable housing in New Zealand. Similarly, Santamouris and Vasilakopoulou (2021) identified overpopulation, rising family incomes, and cultural norms as influential factors driving the demand for sustainable building designs. Health and safety considerations are also essential social drivers aimed at addressing indoor health requirements to mitigate disease transmission risks. Strategies such as effective ventilation design, thermal comfort measures, and universal design for individuals with disabilities are integral to these efforts.

Adisa & Simpeh (2021) highlighted security concerns as social drivers in student housing sustainability. The mixed-method study found that features like access control systems, weapon detectors, security alarms, and electronic coded locks are increasingly being implemented in South Africa. In a related study, Simpeh and Adisa (2022) identified safety measures as significant social drivers for sustainable university buildings at the University of Cape Town, noting the importance of burglar bars on doors, closed-circuit television (CCTV), lifts for persons with disabilities, and weapon detectors. Overall, these studies underscore the complex nature of social drivers to enhancing sustainable indoor environmental energy practices. By addressing health, safety, security, and social awareness issues, stakeholders can enhance the effectiveness of energy sustainability initiatives in housing. This holistic approach is essential for fostering environments that limitedly prioritize energy efficiency but also foster the well-being of residence.

5.2.3 Economic and financial drivers for sustainable building design

Economic drivers and financial drivers are often used interchangeably, but they have distinct meanings in the context of sustainable building design. Economic drivers are typically linked to market acceptance of sustainable designs, while financial drivers focus on the costs associated with

adopting and implementing these designs. Empirical studies have documented these relationships extensively. Windapo (2014) identified rising energy costs as the most significant economic driver for sustainable building adaptation. Liu et al. (2020) emphasized that building value and sustainability gains also serve as important drivers. The competitiveness of the residential market is closely linked to revenue and productivity, with the cost-saving benefits of sustainability influencing investment decisions. Sustainable buildings are viewed as long-term investments, which further underscores the economic viability. Li et al. (2019) supported this perspective by noting that increases in maintenance, health and safety concerns, operational costs, and energy savings are critical economic drivers.

Geh et al. (2021) utilized a Delphi survey to assess the drivers of sustainable technologies in South Africa, finding that financial gains, cost reductions, social influences, and sustainable performance were significant factors. Rispoli & Organ (2019) evaluated the drivers and challenges of energy efficiency through semi-structured interviews, identifying climate change as a key driver while also noting that the costs associated with improvements can present both a driver and a challenge. Tan et al. (2011) found a positive relationship between the adaptation of sustainable buildings and productivity, suggesting that sustainable designs contribute to increased costs but enhance contractors' competitiveness and resource efficiency. Other scholars categorize economic drivers into life cycle costs. Haugbølle & Raffnsøe (2019) identified life cycle costs as an economic driver for sustainable buildings, particularly highlighting operational costs such as cleaning, which can be as high as energy costs.

Ilg et al. (2016) also assessed life cycle costs related to sustainability, finding that material and energy consumption costs increase by approximately 10% annually. The affordability of construction materials significantly influences the adaptation of sustainable buildings. Further, the

selection of sustainable materials is driven by factors such as resource efficiency, energy efficiency, indoor air quality, water affordability, and occupant satisfaction (Ilg et al, 2016). Some researchers argue that the adoption of sustainable materials results from high maintenance costs, health considerations for users, productivity enhancements, and occupant comfort. Others contend that using sustainable materials should improve indoor air quality, reduce maintenance needs, enhance flexibility in building design, save energy, and lower overall building configuration costs (Alhusban et al., 2022; Cuce et al., 2019). Commercial viability has also emerged as an important economic indicator for sustainable buildings. Pan and Pan (2021) identified commercial viability as a crucial economic driver for sustainable design, noting that investors are more likely to invest in sustainable buildings based on potential productivity gains through energy reduction. They emphasized that understanding the relevance of adopting sustainable practices is indispensable during the design phase.

Similarly, Bond (2010) found that investors prioritize financial certainty and viability when considering sustainable buildings, indicating that economic returns play a significant role in determining commercial viability. In summary, economic and financial drivers are integral to understanding the adoption of sustainable buildings. By considering the rising energy costs, life cycle costs, material affordability, and commercial viability, stakeholders can better navigate the complexities associated with implementing sustainability in building design.

2.6 Barriers of sustainable residential building design and construction

The emergence of sustainable design aimed at achieving energy sustainability across various building sectors has received limited attention in terms of implementation. Sustainable building designs, as categorized by Westermann and Evin (2019), include the adaptation of green buildings and vernacular architecture. Additionally, there is a perspective that sustainable design can also be

applied to older buildings requiring retrofitting. However, these innovations face numerous challenges, which have been classified into technical, environmental, and social barriers. Other studies categorize these challenges as financial, technological, and organizational.

Ben Mahmoud et al. (2022) identified five key challenges to implementing sustainable building design: management issues, legal barriers, environmental concerns, technical difficulties, and financial constraints. The research highlights that these challenges can be both human and environmental in nature and are influenced by the organizational maturity level and cultural context of a country. The relationship between these barriers significantly impacts the ability to ensure energy sustainability across various sectors. Research indicates that effective design choices facilitate the selection of sustainable building materials, which can reduce the environmental impacts related to construction. This is particularly imperative during the design phase, where considerations of physical environments can affect both outdoor and indoor environmental quality. Other studies have shown that greening the built environment is linked to reductions in pollution and noise levels (Ning et al., 2019; Song et al., 2021). For example, Song et al. (2021) identified limited site access as a crucial factor for enhancing environmental sustainability in design. Chan (2019) pointed out that building designers often overlook the expertise of design implementors, which affects implementation costs. Aside, the lack of knowledge regarding the relevance of environmental sustainability and well-defined methods for reusing, reducing, and minimizing both outdoor and indoor qualities has also been recognized as a barrier.

Chen et al. (2022) raised concerns about safety and health risks due to exposure to contaminated substances as significant challenges. Empirical studies have confirmed these relationships and highlighted barriers across various categories: organizational, environmental, financial, cultural, political, personal, and technological. In terms of building design elements affecting energy

consumption, several studies emphasize the importance of factors such as building orientation, design complexity, building envelopes, window glazing measurements, and indoor circulation spaces (Gupta & Deb, 2023; Homod et al., 2021).

2.6.1 Knowledge and Awareness of Sustainable Building Designs

Knowledge and awareness of sustainable buildings significantly influence investment decisions in the construction sector. Wu et al. (2019) highlight that a lack of environmental awareness regarding sustainable designs, an immature sustainable building environment, and insufficient implementation of environmental guidelines adversely affect sustainability outcomes. Similarly, Chan et al. (2019) identified issues in Hong Kong such as resistance to change and inadequate institutional support as barriers to effective implementation of sustainable designs. Tokbolat et al. (2020) further emphasize that a lack of awareness of environmental standards among sustainable building designers hampers the implementation efforts. The study in Kazakhstan supports this claim, revealing that addressing environmental challenges is crucial for enhancing sustainability in design implementation and improving the efficiency of construction materials and resources. They identified lack of awareness and education as key barriers affecting sustainability. The absence of awareness regarding sustainability in building design has emerged as a recurring theme in various studies.

Ahn et al. (2013) conducted an in-depth literature review and interviews to identify barriers to sustainable construction in the U.S. They found that challenges limited skills and knowledge among constructors as critical barrier of sustainable practices. The study suggested a thorough review of design sustainability. Liu et al. (2020) found that a lack of awareness regarding the necessity for sustainable designs negatively impacted design implementation in China. In Ghana, Afful et al. (2022) identified the lack of integrated design as the most significant barrier to effective

implementation of sustainable design, attributing it to insufficient awareness about incorporating sustainable designs into buildings. Opoku et al. (2019) also noted that lack of knowledge about sustainability affects sustainable buildings. Kumara et al. (2016) observed similar issues, highlighting inadequate performance from sustainable building vendors and a lack of maintenance services as critical barriers of sustainable buildings.

Fathalizadeh et al. (2022) pointed out lack of understanding regarding the potential benefits of sustainable buildings as critical knowledge barrier of sustainable building. Alemayehu et al. (2022) found that contractors' attitudes toward implementing sustainable building designs were significant barriers. The results indicated that relative significance index and strength consensus metrics played a role in this dynamic. Ma et al. (2022) identified constructors' experience and capabilities, and system inertia as additional barriers. Okwe et al. (2022) reported insufficient awareness levels, resistance to change, and poor acceptance levels regarding sustainable buildings as key obstacles. Taat et al. (2022) echoed these sentiments by identifying resistance to change, knowledge gaps, and insufficient education on the necessity for sustainable designs as significant barriers. Debrah et al. (2022) highlighted that a lack of awareness regarding the benefits of sustainable design was a major barrier for implementing sustainable designs. Similar arguments about the impact of inadequate awareness on energy sustainability are presented by Misopoulos et al. (2023), who conducted a systematic review to understand the barriers to adopting sustainability practices within the UK construction sector. The findings indicated a higher association with environmental sustainability than with social factors, emphasizing that knowledge-related challenges were significant barriers affecting best practices. Drivers influencing levels of awareness have received varied interpretations across studies.

For instance, Datta et al. (2023) identified a shortage of experts as a major barrier to implementing sustainable construction projects using Building Information Modelling (BIM). Other factors include cost reduction opportunities, environmental benefits, enhanced material usage efficiency, social considerations, and overall productivity improvements. Carlander and Thollander (2023) evaluated barriers to adopting energy-efficient building construction in Sweden and found risks associated with financing and inertia ranked high among challenges; however, knowledge gaps and fears among implementers were considered less significant. Fitriani and Ajayi (2023) assessed barriers to sustainable building construction in Indonesia and identified critical issues such as lack of knowledge, standards deficiencies, financial constraints, and poor building design practices. The study indicated that cost delays and resistance to adopting new practices were more pronounced than issues related to incentives or government regulations. Rabea'Hadi et al. (2023) examined challenges surrounding the profitability of green buildings and found that while consumers recognized benefits like improved client retention and reduced operating expenses associated with green buildings, there remained substantial knowledge gaps regarding initial investment costs.

In South Africa, Amoah & Smith (2024) noted challenges such as limited understanding of high costs related to green building retrofitting processes affecting investments in existing residential structures. Hu (2024) similarly highlighted a lack of transparency in cost estimation as a critical barrier facing affordable sustainable building designs. Jaradat et al. (2024) found knowledge gaps within Jordan's construction sector regarding the incorporation of sustainable building requirements into design processes while also noting insufficient public awareness about the positive environmental impacts associated with adopting sustainable buildings. In Ghana, Dadzoe et al. (2024) reported a generally positive attitude toward adopting green construction practices;

however, they found that many stakeholders lacked skills and experience in green building construction techniques. Simpeh et al. (2024) also noted that residents had moderate knowledge about green technologies applicable to residential development in Ghana; approximately 82% expressed varying levels of understanding regarding these technologies.

2.6.2 Environmental barrier/ building materials impacting sustainability of buildings

Inadequate building materials can significantly impact the sustainability of buildings. Recent studies have raised concerns about the use of sustainable materials, highlighting challenges in the adoption that have received limited research attention. For instance, Pham et al. (2020) found that the lack of implementation of sustainable standards and a low level of implementation processes, coupled with limited availability of sustainable building materials, hinder sustainability efforts. Durdyev et al. (2018) noted a reluctance to embrace sustainable design, along with a lack of knowledge and awareness, which further complicates the situation. Poor selection of materials can adversely affect the longevity of buildings, leading to environmental repercussions.

Addy et al. (2021) argue that environmental challenges are not immediate concerns for adopting sustainable buildings in developing countries, particularly in Sub-Saharan Africa (SSA). Instead, economic, regulatory, financial, knowledge-related, technical, and social barriers take precedence. Chrisino et al. (2021) conducted a review on drivers of sustainable energy-saving technology in Brazil and identified financial, political behavior, market dynamics, professional factors, and technological issues as critical elements. Ahn et al. (2013) conducted an extensive literature review and interviews to identify barriers to sustainable construction in the U.S., finding that challenges included enhancing indoor environmental quality, waste reduction, and energy conservation. Fathalizadeh et al. (2022) pointed out insufficient collaboration among

environmental organizations and research institutions as well as a general lack of understanding regarding the potential benefits of sustainable buildings.

2.6.3 Organization/enforcement barriers for implementation sustainable building designs

Organizational barriers significantly hinder the design and implementation of sustainable buildings. These barriers are often intertwined with other challenges, making it difficult to address them in isolation. Many scholars classify organizational support as a critical driver of sustainable building design. Key organizational barriers include a lack of priority given to sustainability, poor communication, absence of guidelines, and entrenched organizational norms and beliefs (Albalkhy & Sweis, 2021). Additionally, Chan and Adabre (2019) highlighted that organizational delays and insufficient management support adversely impact the adaptation of sustainable buildings. Due to the limited examination of organizational barriers in isolation, studies have struggled to identify the specific effects on energy sustainability. For example, Charef et al. (2021) assessed barriers to sustainable design and categorized 18 approaches into organizational, social, economic, political, and environmental concerns. The analysis indicated that many barriers were related to organizational issues. Richardson & Lynes (2007) conducted a similar study in Canada focused on four key indicators of sustainable buildings on campus. They found that a lack of facilitation in communication between professional designers and construction managers, as well as insufficient organizational commitment to setting and achieving sustainability targets, were critical obstacles. Furthermore, challenges related to internal leadership among stakeholders with decision-making power were identified as essential for successful sustainable design implementation.

Kanters (2020) expanded on these findings by noting that the building industry's lack of political dependency and prioritization, along with its conservative nature, posed significant challenges. Hoxha and Lecaj (2022) echoed this sentiment, emphasizing the need for better integration of

sustainability in design processes and enforcement of sustainability laws as key priorities. In Nigeria, Omopariola et al. (2022) identified several organizational barriers to assessing sustainable construction, including organizational poverty, inadequate construction policies, a shortage of professionals skilled in sustainable building practices, and the absence of historical data. Masia et al. (2020) found that the lack of benchmark data on the performance of sustainable buildings and insufficient incentives for adopting such designs were significant challenges. Hyarat et al. (2022) reported that a lack of awareness regarding the relevance of sustainable design and inadequate guidelines for implementing these designs were critical barriers to adoption. Hall et al. (2022) argued that management's lack of awareness is not the only factor contributing to organizational challenges; they also noted that low client demand for sustainable designs, high construction costs, cultural issues, and delays in obtaining necessary licenses affect implementation. In-house and external organizational management can also serve as barriers to support for adopting sustainable buildings. Tan and Gumusburun (2022) found that a lack of management support was a key barrier facing sustainable design adaptation. They noted that while awareness and communication were moderate barriers, inadequate incentives and lack of education on sustainable designs represented significant obstacles. Al-Mohammed's study corroborated these findings by identifying the absence of guidelines for implementing sustainable design and a lack of knowledge regarding the cost-benefit analysis of such designs as critical issues.

Kineber et al. (2022) found that management-related barriers were among the most significant factors impacting the implementation of sustainable design practices. Social issues such as norms and beliefs also play a role in hindering implementation efforts. Adabre et al. (2022) noted that weak enforcement of development controls and bureaucratic processes contributed significantly to institutional challenges surrounding sustainability initiatives. Policy instability was identified

as another major organizational barrier. Chan et al. (2019), in the evaluation of experiences implementing sustainable designs in Hong Kong's construction industry using structural empirical questionnaires, found that a lack of standards for sustainable design, inadequate institutional support, and resistance to change were major obstacles.

2.6.4 Legal/ Regulatory Barriers for implementation of sustainable buildings

The recognition of organizational barriers is crucial in the design and implementation of sustainable buildings. These barriers are often intertwined with other challenges, and many scholars identify organizational support as a key driver for sustainable building design. Critical organizational barriers include a lack of priority assigned to sustainability, poor communication, absence of guidelines, and entrenched organizational norms and beliefs (Albalkhy & Sweis, 2021). Additionally, Chan and Adabre (2019) noted that organizational delays and insufficient management support negatively impact the adoption of sustainable building practices. Due to the limited exploration of organizational barriers in isolation, studies have struggled to quantify the specific effects on energy sustainability.

For instance, Charef et al. (2021) categorized 18 approaches to sustainable building into organizational, social, economic, political, and environmental factors, highlighting that many barriers stem from organizational concerns. Richardson & Lynes (2007) conducted a study in Canada focusing on four key indicators of sustainable buildings on campus. They found that communication gaps between professional designers and construction managers hindered progress. Furthermore, the lack of organizational commitment to setting and achieving sustainability targets was identified as a significant obstacle, along with challenges related to internal leadership among decision-makers. Kanters (2020) expanded on these findings by indicating that the building industry's lack of political dependency and prioritization, coupled with

its conservative nature, posed substantial challenges. Hoxha & Lecaj (2022) echoed this sentiment, emphasizing the need for better integration of sustainability in design processes and enforcement of sustainability laws. In Nigeria, Omopariola et al. (2022) identified several organizational barriers to assessing sustainable construction, including poverty within organizations, inadequate construction policies, a shortage of professionals skilled in sustainable practices, and the absence of historical data. Masia et al. (2020) found that the lack of benchmark data on the performance of sustainable buildings and insufficient incentives for adopting such designs were significant challenges.

Hyarat et al. (2022) reported that a lack of awareness regarding the relevance of sustainable design and inadequate guidelines for implementing these designs were critical barriers to adoption. Hall et al. (2022) suggested that management's lack of awareness is not the only factor contributing to organizational challenges; they also noted low client demand for sustainable designs, high construction costs, cultural issues, and delays in obtaining necessary licenses as influential factors. In-house and external organizational management can also serve as barriers to support for adopting sustainable buildings. Tan & Gumusburun (2022) found that a lack of management support was a key barrier facing sustainable design adaptation. They noted that while awareness and communication were moderate barriers, inadequate incentives and lack of education on sustainable designs represented significant obstacles. Al-Mohammed's study corroborated these findings by identifying the absence of guidelines for implementing sustainable design and a lack of knowledge regarding the cost-benefit analysis of such designs as critical issues. Kineber et al. (2022) found that management-related barriers were among the most significant factors impacting the implementation of sustainable design practices. Social issues such as norms and beliefs also play a role in hindering implementation efforts. Adabre et al. (2022) noted that weak enforcement of

development controls and bureaucratic processes contributed significantly to institutional challenges surrounding sustainability initiatives. Policy instability was identified as another major organizational barrier. Chan et al. (2019), in the evaluation of experiences implementing sustainable designs in Hong Kong's construction industry using structural empirical questionnaires, found that a lack of standards for sustainable design, inadequate institutional support, and resistance to change were major obstacles. In summary, organizational barriers present considerable challenges to effective implementation of sustainable building practices. Addressing these barriers through improved communication, management support, clear guidelines, and fostering an organizational culture that prioritizes sustainability is essential for advancing energy sustainability initiatives in the construction sector. By recognizing the interconnectedness of these barriers with other challenges—such as financial constraints or regulatory issues—stakeholders can develop more comprehensive strategies to promote sustainable practices effectively.

The implications of inadequate building materials on energy sustainability are profound. Recent studies have cautioned against relying solely on traditional materials without considering the environmental impact. For example, Pham et al. (2020) highlighted that insufficient implementation of sustainable standards and limited availability of sustainable materials hinder progress toward sustainability goals. Durdyev et al. (2018) pointed out that reluctance to adopt sustainable designs stems from a lack of knowledge and awareness within organizations. They also noted that poor material selection can adversely affect the longevity of buildings, leading to increased environmental impacts over time. Addy et al. (2021) argued that environmental challenges are often overshadowed by economic considerations in developing countries, particularly in Sub-Saharan Africa (SSA). Chrisino et al. (2021) conducted a review on drivers for

sustainable energy-saving technology in Brazil and identified financial factors alongside political behavior as critical influences. Hussain et al. (2023) assessed key barriers to adopting green buildings in Pakistan and found regulatory issues, socio-cultural factors, resource-related challenges, and government policies as significant obstacles.

2.6.5 Social barriers influencing implementation of sustainable buildings

Social barriers significantly influence sustainable building decisions, and understanding these barriers is essential for effective adaptation of sustainable design. Various studies have highlighted the context and impact of social barriers on sustainability in construction. For instance, Tokbolat et al. (2020) found that social barriers affect the use of efficient construction materials, while Kineber et al. (2023) measured contributions from 45 barriers related to sustainable twin buildings, identifying social barriers as less critical compared to legacy, connectivity, security, and data uncertainty. Dalirazar & Sabzi (2023) conducted a comparative assessment that revealed social and economic barriers ranked higher than financial and knowledge-related barriers. In contrast, Oke et al. (2023) found that when assessing the adoption of cloud computing for sustainable buildings in developing countries, social barriers were significant, alongside economic and communication barriers. Munaro et al. (2020) performed a systematic review on sustainable buildings and identified challenges related to the reuse of building products after the lifespan, as well as issues like lack of product recovery and complex building designs that hinder sustainability strategies. Zhong et al. (2022) pointed out that complexities in sustainable biophilic designs can have rebound effects on biodiversity, health, well-being, and productivity. Zhang et al. (2021) confirmed that the complexities associated with sustainable buildings present challenges in achieving optimal heat recovery and maintaining indoor thermal comfort while ensuring stable building performance.

Conversely, Jalali et al. (2022) showed that optimizing complex sustainable designs could lead to improvements in natural lighting, thermal load management, and usable space through genetic algorithms and parametric modeling. Tokede et al. (2022) conducted a life cycle sustainability assessment of sustainable buildings in Australia and found that social factors contributed significantly to building life cycle impacts—up to 85%—with an estimated cost impact exceeding \$3 million. The study recommended material substitution as a pathway to achieving net-zero emissions. In Greece, Apostolopoulos et al. (2023) assessed life cycle impacts related to passive housing standards and energy retrofitting measures in Athens. They found that upgrading thermal systems and deep retrofitting of building envelopes drastically reduced socio-environmental effects and carbon dioxide emissions by 95% over a 25-year operational lifespan. The implications of social barriers extend beyond immediate construction practices; they also affect long-term sustainability outcomes. For example, Ogunsanya et al. (2022) assessed nineteen variables to determine barriers to sustainable construction in Nigeria using exploratory factor analysis. They found national policy regulations ranked low compared to knowledge levels, governance challenges, and procurement mismatches.

Babalola & Harinarain (2024) used surveys to identify policy barriers in Nigeria's sustainable construction practices through factor analysis, concluding that regulatory barriers were significant compared to implementation challenges and stakeholder policies. Ohene et al. (2022) ranked the lack of regulations higher than implementation or economic barriers such as uncertain long-term payback periods. Zulu et al. (2023) examined barriers in Zambia using a relative importance index (RII) and found awareness and knowledge gaps were more pronounced than regulatory or financial obstacles. Wang et al. (2023) identified technical barriers as predominant compared to economic or political ones when assessing prefabricated building adoption in China. Other studies have

highlighted government policy support as a recurring theme; for instance, Li et al. (2021) noted inconsistencies in green building policies regarding tax incentives and information service delivery. Zepeda-Gil & Natarajan (2020) observed mixed results regarding institutional regulations on carbon emissions across Latin America, noting progress in regulations but challenges with enforcement. In Sub-Saharan Africa, Anzagira et al. (2019) highlighted mandatory government regulations and awareness campaigns as challenges for sustainable green buildings. Agyekum et al. (2022) pointed out the lack of government incentives and institutional frameworks necessary for effective implementation of green buildings in Ghana. Obeng-Darko (2019) assessed renewable energy regulations in Ghana and identified legal issues such as lack of independence among institutional structures and insufficient regulatory assessments as significant barriers. Linking social barriers to energy audits, Basu et al. (2023) conducted an energy use assessment in university residential buildings in Egypt, finding mismanagement of electricity usage concerning air conditioning and lighting loads. The recommendations included transitioning to inverter air-conditioning systems and incorporating photovoltaic solar systems. Alfaoyzan and Almasri (2023) used energy auditing criteria to examine energy consumption in Saudi Arabian university buildings, finding high consumption levels primarily due to air conditioning systems.

2.6.6 Economic/financial barriers for adaptation of sustainable buildings

Financial barriers are critical challenges to the adaptation of sustainable buildings, particularly in the context of student housing. Numerous studies have explored these barriers, highlighting various factors that hinder the implementation of sustainable designs. For instance, Wadu Mesthrige & Kwong (2018) identified environmental performance as a key criterion for sustainable design implementation, with barriers including high costs, inadequate financial incentives, and structural unsuitability of locations. Mirza et al. (2023) pointed out that a lack of

clarity in building designs is a significant barrier, alongside the incapacity of existing laws to secure financial obligations necessary for facilitating sustainable design implementation. Ahiabu et al. (2022) found that perceived initial costs, technological difficulties in design implementation, and a lack of professional knowledge and commitment were critical barriers in Ghana. Adabre et al. (2022) categorized barriers into social (such as social exclusion and high loan default rates), economic (including high costs of sustainable building materials and inadequate incentives), environmental (like thermal and visual comfort), and institutional barriers (such as bureaucracy and delays in obtaining building permits). Hopkins (2016) assessed the barriers to adopting sustainable buildings on university campuses and found that a lack of financial incentives significantly affected sustainability decisions, alongside students' perceptions regarding financial contributions.

Dalirazar and Sabzi (2020) conducted a cross-country analysis of barriers to adopting sustainable buildings in Sweden, New Zealand, and the United States of America. The study identified high initial costs, lack of demand, and significant design and construction costs as major barriers to sustainable building adaptation. Other scholars have linked financial barriers to fears regarding costs and risks associated with unforeseen expenses during implementation (Lambourne, 2022; Debrah et al., 2022). These fears often deter individuals, institutions, and businesses from adopting sustainable building practices. Financial barriers are frequently attributed to a lack of prior experience with sustainable designs, insufficient performance information, and unfamiliarity with innovative building methods. Investors also face challenges related to potential cost savings, capital costs, and consultancy fees due to contractors' terms and unfamiliarity with sustainable designs. Oluwunmi et al. (2019) highlighted that among school buildings in Brazil, the absence of financial incentives to reduce maintenance costs was a significant barrier. Akomea-Frimpong et al.

(2022) identified long payback periods as a challenge for private financing of sustainable buildings, along with high interest rates and increased initial costs.

Kazemi & Kazemi (2022) studied financial barriers to adopting sustainable buildings in Iran through semi-structured interviews with architects, engineers, facilities managers, and project managers. They found that strict financial policies, improper incentives, unpriced costs, and benefits, anxiety over hidden costs, and initial expenses were major perspectives on financial barriers. In Turkey, Akcay (2023) found that cost and demand were the primary barriers to green building adaptation compared to government-related issues or market challenges. Ayakwa et al. (2022) ranked the lack of market demand as the 13th challenge in sustainable building construction processes in Ghana. Similarly, Akinsulire et al. (2024) assessed barriers to adopting affordable housing solutions and found that financial constraints related to the initial cost of materials outweighed awareness or technical expertise challenges. In contrast, Al Mamun et al. (2023) utilized Partial Least Squares Structural Equation Modeling to examine barriers to green building adoption in Malaysia. The study indicated that environmental literacy and awareness levels were more critical than financial incentives for green building buyers. Gounder et al. (2023) assessed the use of sustainable building materials in Australia using multinomial regression analysis. They revealed that techno-economic challenges were among the main barriers alongside financial costs and resistance to adoption.

2.7 Behavioral control effects on energy sustainability

The human-centered aspect of indoor energy sustainability is heavily influenced by the behavioral control of occupants. Factors such as attitude, perceived personal control, cultural norms, and subjective beliefs play crucial roles in determining how occupants engage with sustainable indoor designs. Research by Nie (2019), and La Barbera & Ajzen (2021) emphasizes that understanding

the relationships between intention, attitude, beliefs, actions, and norms is essential for assessing how occupants adopt sustainable practices. Si et al. (2020) noted that perceived behavioral control, attitudes, and subjective norms vary across different situations and behaviors. Zulu et al. (2022) further highlighted that occupants' subjective norms, trust, and attitudes significantly influence household intentions regarding energy sustainability. However, these factors often have indirect benefits on household attitudes toward adopting sustainable practices. In contrast, Chen et al. (2017) found that perceived behavioral control and attitudes toward energy consumption are strong predictors of energy-saving behaviors. Internal stimuli such as awareness and a sense of responsibility can influence personal norms (Duong, 2023; Biswas & Roy, 2015). Subjective norms related to environmental concerns also positively affect intentions to use indoor energy sustainability systems (Liobikienė et al., 2021; Awais et al., 2022).

Additionally, studies suggest that motivation and incentives can significantly influence occupants' adoption of sustainable practices (Li et al., 2019). The mediating effects of social and personal norms on energy usage have been documented in various studies (Awais et al., 2022; Çakır Yıldırım & Karaarslan Semiz, 2019). Attitudes and perceived norms have consistently emerged as positive predictors of occupants' intentions regarding indoor energy consumption and payment behaviors (Xu et al., 2021; Alipour et al., 2021; Masrahi et al., 2021). This body of research underscores the importance of addressing human behavior in the design and implementation of sustainable indoor environments.

The design of buildings—including orientation, complexity, envelopes, window glazing, and circulation spaces—has a significant impact on energy consumption. Gupta and Deb (2023) and Homod et al. (2021) emphasize that these design factors are critical in determining overall energy efficiency. For example, Li et al. (2020) found that building orientation and floor area ratio were

key determinants in a study of 549 residential buildings in China. Liu and Wang (2022) highlighted that the surrounding environment has a more substantial impact on energy consumption than building envelope performance alone. The research indicated that optimizing building envelopes could lead to a reduction in annual energy loads by approximately 47%. Similarly, Homod et al. (2021) reported that vernacular buildings could achieve up to 47.8% energy savings through effective envelope design. Mostafavi et al. (2021) found that enhancing building envelopes could reduce energy consumption by up to 78.9% compared to relying solely on natural ventilation or optimizing room layouts. Gupta & Deb (2023) noted that insulating building envelopes had the most significant effect on energy savings compared to other design factors. Marouane et al. (2023) assessed building design standards in North African countries and found that optimizing factors such as window shading and HVAC efficiency could lower energy consumption by 31%–56%. The study also revealed variability in building.

Indoor circulation systems also play a crucial role in influencing energy sustainability. Alghamdi et al. (2022) found that optimizing cooling set-point temperatures through effective indoor circulation can significantly reduce indoor temperatures by up to 20%, leading to a corresponding reduction in energy consumption by approximately 41% in educational buildings in Australia. Uddin et al. (2022) assessed the effects of interior design on indoor energy consumption and found that adjustments to interior layouts improved energy performance by 14.9%. Ozarisooy and Altan (2022) noted significant correlations between indoor circulation patterns and heating consumption patterns. Natural lighting also impacts energy efficiency; Al-Yasiri and Szabó (2022) studied natural night ventilation in hot summer conditions in Iraq and found a notable increase in ventilation effectiveness during nighttime hours.

Window glazing is another critical factor affecting indoor energy sustainability. Cherier et al. (2024) assessed the impacts of glazing types on energy savings in Algeria, finding significant benefits from low-emissivity glazing compared to other types. The simulations revealed potential energy savings ranging from 6.92% to 9.8%, depending on climate conditions. De Luca et al. (2022) conducted a glare assessment related to glazing efficiency in Estonia, concluding that static shading reduced visual discomfort by 89% while also decreasing overall energy use by 29.1%. Mahdavinejad et al. (2024) found that self-shading glazing designs improved view quality while enhancing energy savings.

2.8 Summary of chapter

The debate surrounding environmental sustainability continues to evolve, particularly in the context of building design, which has emerged as a core contributor to energy challenges across residential, commercial, and industrial sectors. Evaluations of building envelopes, orientation, glazing, and facades have shown promising outcomes in literature, particularly among residential buildings in the Global North. However, aspects of student housing have largely been overlooked in both the Global North and South. Research indicates that various drivers influence sustainable indoor environments, including social, economic, technical, environmental, and legal factors. Conversely, barriers to sustainable indoor environments encompass financial, organizational, social, economic, regulatory, and cultural challenges. Behavioral aspects related to controlling indoor energy systems reveal both positive and negative relationships with energy sustainability. Subjective norms, personal beliefs, intentions, attitudes, motivations, and cultural norms among occupants are critical indicators for evaluating indoor environmental energy sustainability globally.

In summary, the interplay between building design factors—such as orientation, envelope performance, indoor circulation systems, and window glazing—and human-centered aspects like occupant behavior is essential for achieving indoor energy sustainability. Investigating these factors further, holistically can significantly enhance the effectiveness of sustainable practices within residential buildings while fostering greater occupant engagement with sustainable technologies. By improving awareness around these issues and implementing targeted strategies for design optimization alongside addressing social barriers, stakeholders can promote more sustainable living environments effectively across various regions and sectors.

CHAPTER THREE

SUSTAINABLE BUILDING DESIGN AND SOCIETY: NEXUS OF SOCIO-ENVIRONMENTAL-PSYCHOLOGICAL THEORIES AND BUILDING DESIGN THEORIES.

3.1 Introduction

The discourse on sustainability, particularly in the context of student housing, has increasingly emphasized the need for explicit reviews of energy efficiency and environmental impact. While studies on sustainable building practices have diminished in recent years, there remains a critical need to explore the intersection of energy sustainability and student living environments.

3.2 Theoretical Frameworks in Sustainable Design

Theories from environmental psychology and sustainable design provide valuable insights into how building designs can influence energy consumption. Notably, Nielsen et al. (2021); and Millward-Hopkins et al. (2020) suggest that cultural shifts occur as energy consumption increases. Lokshina et al. (2019) argue that technological adaptation and innovation in building designs can enhance energy efficiency. However, scholars like Hanelt et al. (2021); and Niaki et al. (2019) express confusion about whether these factors increase simultaneously. Various theories offer divergent perspectives on the relationship between social systems and building sustainability. Grum & Kobal Grum (2020) propose that social systems can either block or enhance the operationalization of sustainable practices. A thorough review of these theories—including the Theory of Planned Behavior, Value-Belief Theory, Social Cognitive Theory,

Theory of Reasoned Action, and Social Practice Theory—can clarify how building design and individual behavior affect sustainability. Research indicates that building orientation, design complexity, envelopes, window glazing, and indoor circulation significantly influence energy consumption. Gupta and Deb (2023); and Homod et al. (2021) emphasize that these design factors

are critical in determining overall energy efficiency. For example, Li et al. (2020) found that building orientation and floor area ratio were key determinants in a study of 549 residential buildings in China. Liu and Wang (2022) highlighted that the surrounding environment has a more substantial impact on energy consumption than building envelope performance alone, with optimized envelopes potentially reducing annual energy loads by about 47%. Similarly, vernacular buildings showed potential energy savings of up to 47.8% through effective envelope design (Homod et al., 2021). Mostafavi et al. (2021) found that enhancing building envelopes could reduce energy consumption by as much as 78.9% compared to relying solely on natural ventilation or optimizing room layouts. Gupta and Deb (2023) noted that insulating building envelopes had the most significant effect on energy savings compared to other design factors. Indoor circulation systems also play a crucial role in influencing energy sustainability.

Alghamdi et al. (2022) found that optimizing cooling set-point temperatures through effective indoor circulation can significantly reduce indoor temperatures by up to 20%, leading to a corresponding reduction in energy consumption by approximately 41% in educational buildings. Uddin et al. (2022) assessed the effects of interior design on indoor energy consumption and found that adjustments to interior layouts improved energy performance by 14.9%. Ozarisoy & Altan (2022) reported strong correlations between indoor circulation patterns and heating consumption patterns. Window glazing is another critical factor affecting indoor energy sustainability. Cherier et al. (2024) assessed the impacts of glazing types on energy savings in Algeria and found significant benefits from low-emissivity glazing compared to other types, with potential savings ranging from 6.92% to 9.8% depending on climate conditions. De Luca et al. (2022) conducted a glare assessment related to glazing efficiency in Estonia, concluding that static shading reduced visual discomfort by 89% while decreasing overall energy use by 29.1%. Mahdavinejad et al.

(2024) found that self-shading glazing designs improved view quality while enhancing energy savings.

Social barriers also play a significant role in shaping sustainable building practices across various contexts. Tokbolat et al. (2020) found that social barriers affect the adoption of efficient construction materials, while Kineber et al. (2023) identified social barriers as less critical compared to legacy or connectivity issues. Dalirazar and Sabzi (2023) highlighted that social barrier ranked high alongside economic challenges compared to financial or knowledge-related barriers. Oke et al. (2023) emphasized that social barriers were significant when assessing cloud computing for sustainable buildings in developing countries.

3.4 Understanding the Concept of Sustainable Design Theories

3.2.1 Integral theory of sustainable design

Ken Wilber, an influential American philosopher, introduced Integral Theory as a framework to comprehend the intricacies and processes underlying human cognition and experience (Zeiler, 2022). This theory weaves together various valid theories from diverse fields of knowledge, positing that individuals perceive the world through unique lenses, making multiple perspectives crucial for a comprehensive understanding of phenomena and the world at large (Laszlo, 2007). Integral Theory delineates sustainability through two primary contexts. The first context involves the four quadrants that emerge from fundamental value characteristics (DeKay, 2012). The second context addresses levels of complexity that arise from the developmental stages of individuals, physical systems, cultures, biological evolution, and cognition. The upper left quadrant focuses on individual experiences, highlighting how personal interpretations shape local understandings of nature (DeKay, 2012).

For instance, Evins (2013) illustrates this with examples such as perceptions of green building practices, vernacular architecture, and passive solar designs. The upper right quadrant emphasizes environmental performance; according to Shaikh et al. (2014), this quadrant prioritizes resource sustainability optimization due to the limitations associated with non-renewable resources. Examples include energy efficiency and reduced energy consumption. The lower left quadrant reflects collective understandings of symbolism and worldviews (DeKay, 2012), while the lower right quadrant evaluates interactions within specific contexts (DeKay, 2012). In the realms of construction management and architecture, various scholars have adopted philosophical positions rooted in Integral Theory. DeKay (2012) asserts that Integral Theory should address four key areas as outlined by the quadrants. The first quadrant suggests that buildings should be designed to minimize environmental impacts and reduce energy consumption. DeKay (2012) notes that this assessment can be quantified using measurable criteria. Furthermore, buildings must be well-integrated within the local, regional, and global contexts while considering factors like climate change and urbanization. Additionally, structures should foster positive experiences for diverse users. Donetto et al. (2015) emphasize that buildings ought to promote health, evoke positive emotions, ensure safety and comfort, inspire transformation, and engage all human senses while enhancing connections to nature. Finally, the last quadrant evaluates how well buildings uphold cultural values and convey symbolic meanings.

Foster (2020) argues that architectural designs should reflect local cultural values in an ethically responsible manner. Integral Theory has found applications across various fields including nursing, business, education, psychology, art and religion, social sciences, and sustainable development (Koskinen et al., 2011; Bryde et al., 2013; Lechner, 2014). However, its application in architecture remains limited, with virtually no presence in construction management. A significant gap exists

as Integral Theory seeks to integrate critical areas such as analysis versus creativity and design versus technology—concepts that have transcended traditional design disciplines over recent years. While it acknowledges the importance of building designs in promoting environmental sustainability, it challenges the objectivity surrounding building requirements and barriers as well as individuals' experiences with sustainability systems. These inquiries form the foundation for this study's objectives.

3.3 Concept of Socio-environmental and Psychological Theories

3.3.1 Theory of Planned Behaviour

The Theory of Planned Behavior (TPB) was developed by Ajzen (Ajzen, 2011) to explain and predict human behavior across various contexts. It is grounded on the premise that an individual's intention to perform a behavior can be predicted with considerable accuracy (Ajzen, 2002). The theory posits that perceived behavioral control and intentions account for much of the variance in actual behavior (Bosnjak et al., 2020). More broadly, subjective norms, attitudes, and perceived control are critical in influencing salient behaviors such as control beliefs and normative behavior (Conner, 2020). Positive relationships among these factors, despite some measurement limitations, are vital for successful behavioral predictions.

Intentions, as described in the theory, capture motivational factors that influence behavior, including individuals' willingness and the level of effort they are willing to put into performing a behavior (Sussman & Gifford, 2019). According to Conner (2020), stronger intentions increase the likelihood of a behavior being performed. However, while intentions intuitively seem valid, the interaction hypothesis—that intention and behavior are directly correlated—lacks substantial empirical support (Judge et al., 2019).

Three determinants shape intentions in TPB. The first is attitudes toward the behavior, referring to the individual's favorable or unfavorable evaluation of the behavior (Judge et al., 2019). The second is subjective norms, or the perceived social pressure to perform or avoid a behavior. The third determinant is perceived behavioral control. Si et al. (2020) argue that the comparative influence of these factors on intentions may vary depending on the specific behavior and context.

The TPB has been widely applied in various fields, including building management and energy conservation. For example, Zulu et al. (2022) conducted a systematic review of household intentions to adopt solar energy. The findings indicated that subjective norms, trust, and attitudes significantly influenced these intentions, with trust indirectly affecting household attitudes. Similarly, Duong (2023) assessed energy-saving behaviors among students in Vietnam, finding that perceived behavioral control and external stimuli had strong positive effects on attitudes toward energy savings, while internal stimuli like awareness played a role in personal norms.

Harun (2022) examined residents' appliance usage, showing that perceived behavioral control significantly impacted energy-efficient behavior. Yusliza et al. (2020) also found that energy-efficient behavior in Malaysian households was influenced by environmental awareness more than attitude, using PLS-SEM modeling to draw these conclusions. In Lithuania, Liobikienė et al. (2021) found that subjective norms, particularly environmental concerns, influenced residents' intentions to adopt renewable energy, while financial constraints limited the choices. In Pakistan, Bhutto et al. (2020) used TPB to investigate consumer intentions in adopting energy-efficient appliances, focusing on normative beliefs, environmental concerns, and moral obligations. The study found that normative beliefs positively impacted subjective norms, and socio-demographic factors like gender, education, and age also influenced purchasing behaviors. Similarly, Liu et al. (2021) explored personality traits as factors in energy-saving behaviors in China, finding that

perceived behavioral control played a key role in pro-environmental behavior, while subjective norms influenced introverted individuals less.

Qalati et al. (2022) found that subjective norms, attitudes, and perceived behavioral control all significantly impacted energy-saving intentions and behaviors among Pakistani residents. They extended the TPB framework by including moral responsibility and descriptive norms, showing high predictive power for energy-saving behaviors. Bhutto et al. (2022) confirmed these findings. Suntornsan et al. (2022) applied TPB to study energy-saving behaviors among students with disabilities in Thailand, finding that subjective norms were the strongest predictor of intention, while attitude had the weakest influence.

Gao et al. (2017) examined energy consumption behaviors in China and found that personal and descriptive norms strongly influenced energy-saving intentions. Similarly, Paul et al. (2016) found TPB to be an effective predictor of Indian consumers' green purchasing intentions, with attitude and perceived control being more significant than subjective norms. Nie et al. (2019) noted that while TPB can explain substantial variance in behavior, many questions remain unanswered, especially regarding the scaling limitations of perceived control and belief-based factors (Conner, 2020).

3.3.2 Social cognitive theory

Social Cognitive Theory, established by Bandura in 1986, serves as a robust framework for understanding human behavior and the motivations behind it. The theory emphasizes that human inspiration is significantly influenced by social interactions within an ecosystem, encompassing relationships between individuals and the environments, as well as between individuals themselves. This foundational argument highlights the interplay between social dynamics and individual behaviors. According to Nie et al. (2019), individual behavior encompasses attitudes,

beliefs, emotions, and intentions that shape cognitive capabilities. The influence of the environment on individuals can be seen through the outcomes of the actions, the physical conditions they encounter, and the resources available to them, reflecting the objective circumstances. The theory posits that the reciprocal interactions between environmental factors and individual actions positively affect behavior, suggesting a bidirectional influence. Central to this theory are the concepts of self-efficacy and outcome expectations, which are pivotal in determining cognitive abilities. Bandura describes the relationship among behavior, self-efficacy, and environmental influences as a triadic reciprocity. Self-efficacy refers to an individual's perceived capacity to execute actions necessary to achieve desired outcomes (Rizkalla & Erhan, 2020). High self-efficacy enhances an individual's ability to contribute knowledge within a community, a notion supported by Yang et al. (2020). Furthermore, self-efficacy is linked to increased motivation to engage in environmentally friendly behaviors, even during challenging times.

Yang et al. (2020) asserts that perceptions within a social context can significantly shape individual behavior. As an established theoretical framework, Social Cognitive Theory has been applied across various studies in psychology and sociology. Bandura's research in 1986, 2006, and 2008 consistently demonstrated the utility of this theory in examining the reciprocal influences among behavioral forces, environmental factors, and personal motivations. Ortiz et al. (2020) emphasize that understanding residents' behaviors, awareness, preferences, and needs is crucial when evaluating indoor environmental quality. Previous research has utilized Social Cognitive Theory to elucidate energy consumption behaviors (Zhang et al., 2019; Li et al., 2019) and intentions related to energy purchases (Ali et al., 2019). For example, Shahangian et al. (2021) investigated residential water conservation behaviors in Iran, focusing on psychological factors influencing

conservation practices and behavioral changes among residents. The findings indicated that behavioral intentions were strong predictors of actual behaviors, with self-efficacy emerging as a significant determinant of these intentions.

Conversely, while outcome expectations and self-efficacy had an indirect but notable impact on behaviors, Komendantova et al. (2018) explored social acceptance regarding energy transitions in Iran. The study revealed a direct correlation between energy transition variables and human factors while highlighting conflicting beliefs and perceptions among residents and stakeholders regarding energy deployment. Additional studies have reported positive effects of self-rewarding mechanisms aimed at encouraging young adults to support energy transition policies. Key drivers identified include social outcomes such as norms, trust levels, and access to information. Li et al. (2019) examined occupant behaviors related to energy consumption in the U.S., employing structural equation modeling to show that opportunities positively influenced energy-saving behaviors while motivation played a facilitating role alongside ability. Despite its proven applicability in various contexts, there remains limited exploration of Social Cognitive Theory within the residential sector—particularly concerning student housing. Wang et al. (2019) argue that self-efficacy and behavioral intentions regarding indoor environmental sustainability differ significantly from those observed in typical residential settings. They affirm that personal factors like outcome expectations and self-efficacy can effectively predict energy sustainability among students.

3.3.3 Value-Belief-Norm (VBN) Theory

The Values-Beliefs-Norms (VBN) theory, rooted in Schwartz's (1977) norm activation model, posits those pro-environmental behaviors stem from individual moral norms. This theory suggests that moral actions are motivated by individuals who perceive environmental issues as threats to

other species, the biosphere, and humanity as a whole. Han et al. (2017) explains that VBN articulates the connections among behaviors, beliefs, norms, and values. Research indicates that mediators such as norms and beliefs create a stronger relationship between behavior and values than a direct correlation (Kaiser et al., 2005; Stern, 2000; De Groot & Steg, 2008; Megeirhi et al., 2020). According to the theory, personal norms are grounded in pro-environmental beliefs, including role ascription, awareness of environmental conditions, and the new ecological paradigm (Beall et al., 2021). Values encompass the actions and guidelines necessary for trans-situational independence, contrasting relative reputation (Beall et al., 2021). Examples of values within the VBN framework include openness to change, altruism, biospheric concerns, traditional values, and egoism.

Du and Pan (2021) assert that these values are often documented as actions aimed at protecting the environment from the adverse impacts of human activities. The VBN theory has been extensively applied in pro-environmental research (Tian & Liu, 2022; Minelgaitė & Liobikienė, 2021), focusing on domains such as eco-friendly behavior, green practices, environmentally responsible actions, and ecological behaviors. Davlembayeva et al. (2020) highlight that many of these studies are primarily situated within social psychology. The interplay between VBN and other psychological theories reveals a significant relationship that underscores its applicability. Several scholars have identified VBN as a robust predictor of pro-environmental behavior (Liu et al., 2018; Çakır Yıldırım & Karaarslan Semiz, 2019; Poortvliet et al., 2018). For instance, Chen (2015) utilized Sobel tests to confirm pro-environmental behaviors among residents in Taiwan. The findings indicated both mediating and direct effects of fundamental pro-environmental behavior variables such as belief. Kiatkawsin and Han (2017) employed the VBN framework to evaluate environmentally friendly behaviors among residents, revealing its strong predictive capability for

pro-environmental intentions. These findings illustrate the direct influence of VBN when assessing environmental behaviors. However, empirical studies have predominantly concentrated on personal norms and intentions. For example, Awais et al. (2022) investigated pro-environmental behaviors related to solar energy consumption in Pakistan through surveys. The results indicated that social norms positively influenced both personal norms and pro-environmental behavior. Moreover, personal norms acted as mediators between residents' pro-environmental behavior and the attitudes towards solar energy.

Conversely, Çakır Yıldırım and Karaarslan Semiz (2019) found differing results in the assessment of sustainable water consumption behavior, belief systems, personal norms, and universal values among residents using PLS-SEM. They determined that personal norms were strong predictors of sustainable water consumption behavior and mediated the relationship between responsibility attribution and such behaviors. Supporting this notion, Yeboah and Kaplowitz (2016) identified self-transcendence values and individual norms as significant precursors to pro-environmental behavior reflecting environmental considerations. Specific beliefs had a mediating effect on personal norms concerning pro-environmental attitudes. Hojnik et al. (2021) employed linear regression and fuzzy set qualitative approaches to explore willingness to pay for green energy. The study revealed that moral obligations and social norms significantly influenced willingness to pay for sustainable energy options while considering socio-demographic factors such as education level, age, gender, and income. Despite extensive discussions around personal norms as key drivers of occupants' environmental behaviors, other studies have utilized VBN to assess occupants' intentions (Liobikienė & Poškus, 2019).

For instance, Testa (2016) examined determinants influencing occupants' intentions to change energy consumption habits using trust in information sources and moral norms as variables. The

results indicated strong influences from family and friends along with information provided by private companies on energy consumption behaviors. Similarly, Fornara et al. (2016) used PLS-SEM to predict household intentions regarding renewable energy use. The findings highlighted that information from relatives and friends alongside moral norms were significant predictors of residents' intentions. Gkargkavouzi et al. (2019), also utilizing PLS-SEM to evaluate residents' intentions regarding environmental behaviors, found that these intentions served as primary predictors of actual environmental actions. Additionally, subjective norms and residents' habits emerged as crucial factors influencing these intentions. Awareness of environmental consequences positively affected attitudes, personal norms, perceived behavioral control, and subjective norms.

3.3.4 Social practice theory

Social Practice Theory offers a framework for understanding social actions by emphasizing the role of shared symbolic structures in human knowledge, as articulated by Reckwitz (2002). This theory posits that social practices are routinized actions enacted by individuals, and it has gained traction as a lens through which to explore emerging solutions and strategies in product development, deeply embedded in daily life (Feldman, 2020; Carmichael, 2022; Chibber, 2022; Verduijn & Andersen, 2022). Social practices encompass a range of elements including mental activities, emotions, behaviors, knowledge, and contextual understanding. The effectiveness of social practices relies on the interactions between both actors and observers within a cultural context (Carmichael, 2022). The sustainability of these practice hinges on individuals' effectiveness as actors and the ongoing performances (Wei et al., 2020).

Nevertheless, Social Practice Theory acknowledges that individual actors are often constrained by external factors within and beyond the societal context (Chege & Wang, 2020). The theory particularly focuses on household social practices related to consumption processes, suggesting

that the sources of individual behavior are not merely decision-making processes but rather the evolution of the practices themselves (Chibber, 2022). This indicates that the theory positions individuals' routines, habits, and tacit knowledge as central units of analysis (Holland & Lave, 2019). While Social Practice Theory has been widely applied in behavioral studies, public health, and food science, its application in sustainability research has primarily centered on pro-environmental initiatives. Recent investigations have sought to apply this theory to energy consumption and conservation.

For instance, Stelmach et al. (2020) explored energy-related rules and activities among residents. The findings highlighted social energy practices such as household rules governing building control systems. They reported specific thermal comfort practices—like turning off heating or cooling when no one is home and closing doors during heating or cooling—as well as electricity usage rules that garnered significant participation among residents. Scott and Powells (2020) also employed Social Practice Theory to examine human behavior concerning hydrogen acceptance in global energy consumption. The study identified two critical areas for conservation: heating/cooling practices and the disruption of spaces where hydrogen is utilized. They advocated for future applications of Social Practice Theory in energy conservation efforts. Similarly, Edomah and Ndulue (2020) conducted a study among 259 residents in Lagos, Nigeria, revealing that social practices significantly influence energy consumption patterns. Practices such as home laundry, increased cooking frequency, and showering were found to contribute to higher energy usage. Xu and Chen (2019) investigated social energy practices among low-income residents in China and discovered that these residents engaged in energy-saving behaviors throughout the daytime more than their counterparts. However, barriers such as inaccessibility and affordability were identified as obstacles to enhancing energy-saving practices.

3.3.5 Theory of Reasoned Action

The Theory of Reasoned Action (TRA), developed by Fishbein and Ajzen in 1975, is a foundational model within socio-environmental and socio-psychological frameworks. It is primarily an intention theory that builds upon earlier theories of social psychology, particularly those related to attitudes and persuasion. The TRA posits that the performance of specific actions by individuals is driven by the behavioral intentions, which are influenced by two main factors: attitudes toward the behavior and subjective norms. Fishbein and Ajzen (1975) argue that subjective norms emerge from individuals' perceptions of social pressures regarding their behavior. This means that how individuals believe others view their actions significantly influences the intentions to engage in those behaviors. While attitudes and subjective norms serve as primary predictors of behavioral intentions, other scholars have noted that various external environmental elements can also indirectly affect individual behaviors. A notable aspect of the TRA is its recognition that exposure to new environments necessitates modifications in personal beliefs, leading to changes in attitudes. The TRA is often seen as a precursor to the Theory of Planned Behavior (TPB). Its applications span several fields, including sociology, psychology, health, and business; however, its use in physical sciences remains limited.

Recent studies have explored the application of TRA in energy consumption behaviors. For instance, Wang et al. (2021) utilized structural equation modeling to investigate the impact of electricity prices and habits on residents in China. The findings indicated that electricity prices did not significantly affect consumption levels; rather, residents' habits were a more substantial determinant of electricity use. Similarly, Xu et al. (2021) found that personal norms were the strongest predictor of households' energy-saving intentions, with perceived behavioral control also playing a significant role. Alipour et al. (2021) examined residential decisions regarding energy

savings in Australia, revealing that detailed background information about residents influenced the attitudes and perceived norms related to energy-saving intentions. Du and Pan (2022) conducted a gender-focused study on energy-saving behaviors among university students in Hong Kong, highlighting significant differences between male and female students in the approaches to energy savings based on varying beliefs. Ahmad et al. (2022) assessed the determinants of energy-saving intentions among 511 residents in Pakistan using structural equation modeling. The results identified positive anticipated emotions as a significant predictor of both energy-saving behavior and intentions, with perceived disruption from COVID-19 acting as a positive mediator for enhanced energy-saving behaviors. Supporting this, Zeng et al. (2022) conducted similar research in Pakistan. Ianole-Călin and Druică (2022) employed PLS-SEM to examine residential energy consumption intentions in Romania, finding that the intention to adopt smart grid technologies was significantly influenced by perceived ease of use and usefulness while noting that environmental factors had minimal impact on behavioral intentions.

Masrahi et al. (2021) studied demographic and behavioral characteristics affecting renewable energy adoption across 22 states in the U.S., concluding that household income significantly influenced residents' intentions to utilize renewable energy sources. The model indicated that willingness to pay and perceived behavioral control were key factors influencing these intentions, although attitudes did not show significant effects. Hossain et al. (2022) applied PLS-SEM to analyze pro-environmental behavior concerning energy-efficient appliances among 1,510 residents in Bangladesh. The findings revealed that green trust, environmental knowledge, attitude, and eco-label knowledge significantly correlated with pro-environmental behavior, with green trust serving as a mediating variable enhancing the relationship between eco-label knowledge and environmental behavior.

3.4 Summary of chapter

The theoretical foundations of sustainable energy consumption reveal interconnected premises across various socio-psychological theories, particularly the Social Cognitive Theory, Theory of Reasoned Action, and Theory of Planned Behavior (TPB). Empirical reviews indicate that these theories are instrumental in understanding behavioral control and intentions related to sustainability. The Social Practice Theory and Value-Based Norm Theory also emphasize personal, social norms, and cultural values as significant predictors of behavioral control and intentions. Among these frameworks, the Theory of Planned Behavior has emerged as the most widely utilized socio-psychological and environmental theory in recent research. The TPB highlights the interrelationship between human intentions, perceived social pressures, and perceived behavioral actions as core elements. This framework has been extensively applied in residential energy studies, suggesting that utilizing the TPB to assess student behavioral control regarding indoor environmental energy sustainability in student housing could yield valuable insights. This indicates a theoretical gap concerning students' behavioral intentions towards indoor energy savings, consumption, and adaptation to building energy solutions.

In the context of building design and management, the Integrated Design Theory's four-quadrant framework has demonstrated its utility not only in meeting design requirements but also in addressing cultural, environmental, and residential market implications. This study aims to integrate the principles of both Integrated Design Theory and the Theory of Planned Behavior to achieve its objectives.

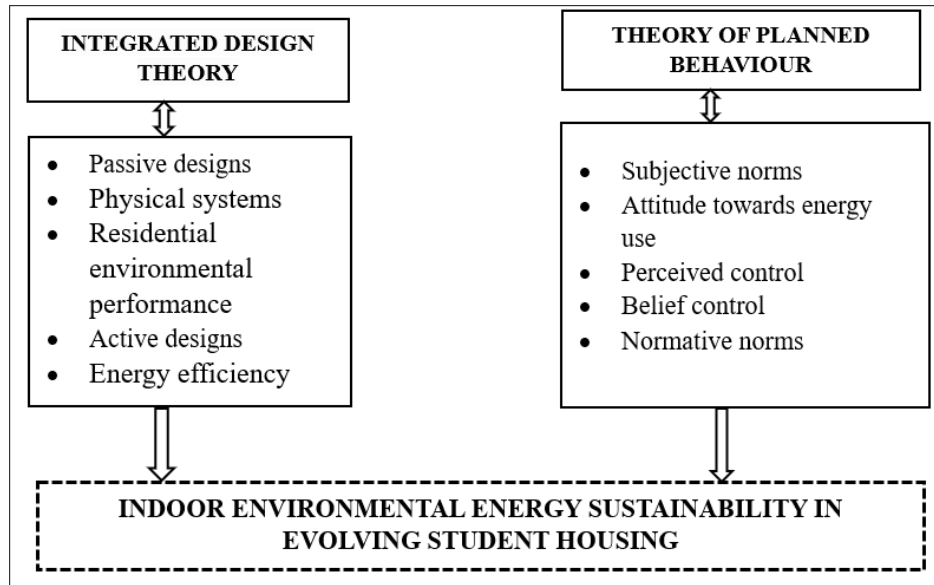


Figure 3.1 Theoretical framework of study

Source: Researcher's construct, some idea adopted from: Ajzen, 2011; Koskinen et al., 2011; DeKay, 2012; Nie et al., 2019).

CHAPTER FOUR

EMPIRICAL REVIEW AND CONCEPTUAL FRAMEWORK

4.1 Introduction

This section reviews key empirical studies relevant to the research objectives, focusing on three main areas: building design requirements, drivers and barriers to adopting sustainable building design, and the behavioral control of occupants regarding indoor environmental energy sustainability. The first area of focus is building design requirements, which encompass various factors such as building orientation, envelope, height, plan geometry, and spatial dimensions. These elements significantly influence energy sustainability by optimizing natural light, ventilation, and thermal performance. Studies have shown that well-designed buildings can reduce energy consumption and enhance occupant comfort, thereby contributing to overall sustainability goals. The second area examines the drivers and barriers associated with adopting sustainable building design. Factors such as regulatory frameworks, financial incentives, and community engagement play crucial roles in promoting sustainable practices.

Conversely, challenges like high initial costs, lack of awareness, and insufficient technical expertise can hinder the implementation of sustainable designs. Understanding these dynamics is essential for developing strategies that facilitate the transition to more sustainable building practices. The third area of focus is behavioral control of occupants in relation to indoor environmental energy systems. Research indicates that occupants' behaviors significantly impact the effectiveness of energy-saving measures. The Theory of Planned Behavior (TPB) has been particularly influential in this context, as it highlights the role of intentions shaped by attitudes, subjective norms, and perceived behavioral control. Empirical evidence suggests that when

occupants are aware of the energy consumption patterns and feel empowered to make changes, they are more likely to engage in sustainable practices.

4.2 Integrated building design

Empirical evidence consistently shows that both active and passive design strategies significantly influence energy performance in buildings. Elaouzy & El Fadar (2022), through in-depth interviews, highlighted that integrating these strategies enhances the environmental, social, and economic sustainability of buildings, leading to 66.2% energy savings and a 52% reduction in life cycle costs. This is further supported by Zhang et al. (2022), demonstrating the effectiveness of passive and active strategies.

Extensive studies have explored various building elements such as building envelope, geometry, glazing, and orientation as key determinants of indoor energy sustainability. For instance, Elghamry & Hassan (2020); and Blanco et al. (2019) found that building envelope design and orientation play crucial roles in optimizing energy efficiency. Additionally, Wheeler et al. (2022); and Tabadkani et al. (2019) emphasized that factors like geometry, façade design, and glazing systems significantly influence energy sustainability both indoors and outdoors. Studies by Al-Saggaf et al. (2020); and Sahu (2022) further indicate that building height, circulation layouts, and interior dimensions are also key contributors to energy efficiency.

Concerning building orientation, Kumar et al. (2022) found that it impacts energy use more significantly than building shape, as orientation enhances the building's thermal and visual comfort. Ochedi et al. (2022) echoed this, noting that building orientation in Nigeria is a primary driver of energy efficiency. Alwetaishi (2022) also showed that shading devices, window-to-wall ratio, and building orientation are critical variables for optimizing energy consumption, especially in residential buildings. Similarly, Tahmasebinia et al. (2022) found that building orientation and

shape significantly affect energy consumption, particularly in diamond-shaped buildings. Xye et al. (2022) demonstrated that building design optimization could reduce carbon emissions and energy usage by adjusting variables like window type and wall insulation thickness.

Shading strategies have also been found to contribute to energy savings. Rana et al. (2022) discovered that the use of shading devices, such as vertical and horizontal blinds, in Bangladesh reduces energy consumption, particularly in southwestern areas vulnerable to high energy use. Ruggiero et al. (2022) found that light shelf configurations and material choices can significantly affect indoor energy consumption, emphasizing the impact of building geometry on energy needs.

When assessing building materials, studies indicate the effectiveness of indigenous materials in tropical regions. Jegede & Taki (2022) revealed that indigenous building materials optimize thermal comfort, reducing interior temperatures by 8%. Similarly, Khaliq & Mansoor (2022) noted that double-layered windows and cavity walls improve energy savings by enhancing insulation, resulting in an 8% and 6% energy reduction, respectively.

For building envelope and massing, various studies suggest the importance of massing typologies and façade materials. Savvides et al. (2019) found that spine massing increases energy use, particularly in multi-story buildings, while De Luca et al. (2022) noted that maximizing sun exposure in buildings can save up to 56% of energy. Additionally, Elakkad & Ismaeel (2021) emphasized that early design-stage decisions, particularly concerning building massing, can significantly impact energy savings by optimizing daylight penetration and material selection. For building façades, Balali & Valipour (2020) found that thermochromic and photovoltaic materials significantly reduce environmental impacts, outperforming traditional materials. Mirshojaeian et al. (2020) also demonstrated that indigenous building facades generate less thermal energy than modern buildings.

Glazing requirements further support energy sustainability. Akram et al. (2023) highlighted the energy-saving potential of semi-transparent photovoltaic devices and glazed windows, reducing peak cooling loads by 28%. Liu & Wu (2022) similarly noted that smart glazing windows can achieve annual energy savings of up to 37% by enhancing indoor illumination and energy efficiency. Other studies, such as those by Pathirana et al. (2019) and Obrecht et al. (2019), explored the relationship between building orientation, shape, and glazing to optimize energy consumption and indoor comfort.

Limited research has explored the impact of circulation and space layout on energy sustainability. However, some studies, like those by Ahn & Sohn (2019); and Han et al. (2020), indicate that low-rise buildings consume less energy than high-rise structures. Khajavi et al. (2021) suggested that natural ventilation strategies, such as optimal stair layout and interior ventilation connections, can reduce energy consumption, particularly during warm seasons. Wu et al. (2021) also found that building group layout, compared to courtyard designs, significantly impacts energy consumption, emphasizing the importance of spacing for daylight in reducing energy use.

4.3 Drivers of Indoor Environmental Energy Sustainability Design

Previous studies have identified various drivers influencing the adoption of sustainable building design, encompassing economic, social, technological, environmental, and government policy factors (Munaro et al., 2020; Chan & Anabre, 2019). However, there is a gap in the research concerning the specific drivers of sustainable design within student housing. For example, economic drivers of sustainable residential designs typically include affordability, climate change mitigation, aesthetics, energy reduction, and knowledge drivers, as well as the need for inclusivity and compliance with government policies (Gharehbaghi et al., 2022; Orsini & Marrone, 2019; Mi

et al., 2020; D'Urso & Cicero, 2019; Faraj et al., 2022; Lu et al., 2020; Li et al., 2019). These are commonly studied in regions of the Global North.

One study by Lam (2022) used regression analysis to investigate aesthetic design drivers in buildings, concluding that flexibility in stair design, room layout, and movement ease were critical to enhancing comfort. Financial factors such as affordability, life cycle cost, commercial viability, and the drive to reduce energy consumption have also emerged as key determinants in sustainable residential design. For instance, Oke et al. (2024) used the relative importance index and factor analysis to explore the financial drivers of sustainable construction in Nigeria, identifying energy cost savings, job creation, return on investment, and cost-effectiveness as significant considerations, with energy savings being the most prominent. Similarly, McCord et al. (2024) found that economic incentives, such as energy use premiums, enhanced sustainability in construction. Studies like Zhou & Lund (2023) further highlighted the role of fair energy-sharing mechanisms in improving system efficiency.

Life cycle cost (LCC) analysis has been applied in various sustainability assessments. For example, Gulcimen et al. (2023) found that 80% of the total LCC in university campuses stemmed from energy costs, while Tsantili et al. (2023) reported a 12.67% reduction in LCC and a 17.6% decrease in energy costs following the adoption of high-efficiency chillers and boilers in European university buildings.

Health and comfort have also emerged as significant drivers of sustainable building design. Tran & Huang (2022) used PLS-SEM to assess the influence of health, thermal, and visual comfort on building performance, emphasizing the importance, although the study did not fully explore energy sustainability. Knowledge-based drivers have also gained attention, with Hossain et al. (2020)

identifying innovation and the energy sustainability gap as key factors influencing sustainable design, though the impact of these drivers on energy efficiency remains underexplored.

Inclusivity, another social driver, has been examined by Fatourehchi & Zarghami (2020), who identified the importance of collaborative indoor environments and energy appliance impacts in improving the quality of life for disabled occupants. Studies in Africa have also noted the ripple effects of health-related drivers, with Ebekozi et al. (2024) identifying health and occupant comfort as primary considerations in sustainable housing design. Wang et al. (2024) observed that adopting green buildings led to reduced energy consumption and improved occupant health in African contexts. In the same vein, Jia et al. (2021); and Appau et al. (2024) both found that optimizing passive design to control indoor environmental quality (IEQ) and thermal comfort was crucial for student housing in Ghana.

In the Global South, fewer studies have been conducted on the drivers of sustainable building design. Saidu and Yeom (2020) identified affordability and adaptability as key economic drivers in sustainable construction, while Agyekum et al. (2022) highlighted investment returns and emerging business opportunities as critical market drivers in Ghana. Assylbekov et al. (2021) and Tokbolat et al. (2020) also pointed to economic factors such as energy efficiency, operational costs, and climate change as significant influences in Kazakhstan, with economic drivers ranking third after social and environmental factors in the study.

Lastly, studies focused on environmental and design drivers have revealed varied insights. For instance, Testa et al. (2021) emphasized the importance of socio-demographic factors in driving green consumption, while Seifhashemi & Elkadi (2022) noted the critical role of aesthetics in cost and energy savings within UK residential buildings. In Ghanaian student housing, Appau et al. (2023) identified challenges related to stair design flexibility and cleanliness as barriers to

sustainability. Moreover, Keser Aschenberger et al. (2023) reported that reducing stress outcomes through effective space design was a crucial driver in academic institutions.

These findings underscore the complexity of drivers influencing sustainable building design, especially in different geographic regions and building types.

4.4 Barriers of Indoor Environmental Energy Sustainability Design

Challenges to the adaptation of sustainable building design vary significantly across countries and markets; however, literature has identified common barriers through diverse methodological approaches. Emerging obstacles to sustainability include issues related to the standardization of building materials, financial constraints, social dynamics, regulatory and enforcement concerns, and knowledge gaps. Empirical findings regarding the standardization of building materials are highlighted in a study by Pham et al. (2020), which investigated barriers to adopting sustainable design in Vietnam. The factor analysis revealed that the lack of effective implementation of sustainable standards and a low level of adherence to these processes hinder the adaptation of sustainable buildings. Financial barriers were also prominent; Ahiabu et al. (2022) utilized exploratory factor analysis to identify perceived initial costs as a significant financial obstacle to adopting sustainable building designs. Similarly, Adabre et al. (2022) conducted research in Ghana that uncovered high loan default rates, elevated costs of sustainable materials, and a lack of incentives as critical financial barriers to implementing sustainable designs. Kazemi & Kazemi (2022) further explored financial constraints in Iran, reporting that distortionary fiscal policies, inadequate incentives, unpriced costs and benefits, anxiety over hidden costs, and initial expenses were major financial challenges. Legal barriers have emerged as complexities surrounding sustainable building regulations and a lack of clarity in enforcing these designs. Hoxha & Lecaj (2022) found that the absence of laws governing material strength within sustainability regulations

was common in Kosovo. Additionally, they noted deficiencies in enforcing sustainable building practices. Other studies have highlighted enforcement issues; Kanter (2020) identified a lack of political commitment within the building industry as an enforcement barrier, while Hoxha & Lecaj (2022) reiterated the absence of sustainability laws as a concern. Hyarat et al. (2022) also reported that insufficient guidelines for implementing sustainable building designs constituted an enforcement barrier. Lack of awareness has proven to be another significant barrier to adopting sustainable building design. In Ghana, Afful et al. (2022) conducted a study using exploratory factor analysis among residential buildings and found that a lack of awareness regarding the inclusion of sustainable designs was concerning. Opoku et al. (2019) conducted similar research in Accra, Ghana, identifying a lack of knowledge about sustainability as a key barrier to adopting sustainable building designs. However, these studies did not assess the extent to which these barriers contribute to the implementation of sustainable building designs, indicating potential gaps in understanding the impact on student housing.

4.5 Behavioural control adaptation to sustainable building design

The role of behavioral control in residential energy sustainability has been extensively studied in office, industrial, and commercial buildings. However, studies exploring the relationship between residential behavior and energy consumption, especially in sub-Saharan Africa, are limited. Theoretical frameworks focus on behavioral intentions, norms, attitudes, and cultural effects on energy sustainability, with empirical evidence showing both positive and negative impacts. Researchers like Mba et al. (2023), Sholanke et al. (2022), and Lamberti et al. (2021) highlight psychological drivers, such as health, safety, and comfort, while others like Wang et al. (2023); and Noorzai et al. (2023) emphasize contextual drivers, including ventilation, cooling, heating, and insulation. Physical drivers such as illumination, odor, noise, and temperature have been noted

by Abdollahzadeh et al. (2023) and Xu et al. (2020), while socio-demographic factors (age, education, income, and gender) have been studied by Deng et al. (2021); and Du & Pan (2020).

Du and Pan (2020), for example, used surveys and factor analysis in Hong Kong to explore physical, contextual, and social factors influencing energy-saving behaviors. They found that window operation and air conditioning usage were key behaviors influenced by floor level and seasonality. Liao et al. (2020) used probit regression in China to assess the impact of attitudes and behavioral intentions on energy savings, finding that larger households and older occupants correlated positively with energy-saving decisions. Several studies emphasize the influence of gender on energy behavior. Deng et al. (2021) found that male students consumed more energy than females in Chinese dormitories, while Du and Pan (2022) revealed that gender differences in energy efficiency were significant among university students in Hong Kong, with females demonstrating more energy-saving potential. Similarly, Chen et al. (2017) reported that attitudes and perceived behavioral control strongly predicted energy consumption intentions, with the need for cooling and heating negatively affecting these intentions.

In addition to socio-demographic factors, contextual variables like ventilation systems and thermal comfort have been investigated. Schünemann et al. (2021) and Ahadzie et al. (2021) found that window operation, ventilation behaviors, and the use of air conditioning and fans were significant in reducing energy consumption. In Ghana, the use of fans over air conditioning showed a positive impact on energy savings, though window-opening behavior was less significant. Physiological drivers also play a role in energy consumption. Kostakis (2020) and Niamir et al. (2020) explored how age, education, and regional characteristics impact energy behaviors. Additionally, room illumination and odor were linked to physical aspects of energy consumption. Moadab et al. (2021) noted that smart lighting systems reduced energy use by 50%, while Rucińska and Trzaski (2020)

found that poor lighting design and window parameters affected energy efficiency in educational buildings.

Social drivers influencing energy behaviors are complex and multifaceted. Social interactions and peer influence have been shown to affect behavioral patterns, as highlighted by studies like Wolske et al. (2020) and Baltruszewicz et al. (2023). Window-opening behaviors and changes in clothing have also been linked to energy consumption, as seen in studies by Chen et al. (2021) and Kim et al. (2020). Overall, the behavioral control aspect of residential energy sustainability is influenced by a combination of psychological, contextual, physical, and socio-demographic factors. Empirical studies suggest that energy-saving behaviors are shaped by attitudes, norms, and perceived behavioral control, with significant variations based on gender, age, household size, and physical building characteristics. The literature indicates that enhancing energy sustainability requires a nuanced understanding of these drivers, particularly in the context of sub-Saharan Africa, where such research remains sparse.

4.6 Conceptual framework

4.6.1 Sustainable indoor student housing environmental energy sustainability

Models for ensuring indoor energy sustainability in residential buildings have predominantly relied on physics and material science. However, the unique characteristics of student housing necessitate the development of physio-environmental models that do not only address the physical contributions to sustainability but also consider indoor energy aspects that enhance student comfort, health, and academic performance. Current literature has not sufficiently explored the connection between design drivers and the benefits of energy sustainability. Additionally, critical barriers to sustainable student housing and the environmental energy sustainability of indoor spaces have been under-researched. Behavioral control plays a crucial role as a catalyst for the

effective use of energy control systems, linking directly to sustainable indoor energy practices in student housing. Therefore, this study will utilize the model depicted in Figure 3 to assess critical areas that designers, contractors, institutions, and housing managers should prioritize.

The Theory of Planned Behavior (TPB) provides a relevant framework for understanding these dynamics. Developed by Icek Ajzen (Ajzen, 2011), TPB aims to explain and predict human behavior across various contexts by positing that intentions to perform specific actions can be accurately predicted based on attitudes, subjective norms, and perceived behavioral control. This theory has been widely applied in building management and energy consumption studies. For instance, Zulu et al. (2022) conducted a systematic review assessing household intentions to adopt solar energy, revealing that subjective norms and trust significantly influence these intentions. Rausser et al. (2018) is also of the view that households in EU countries change their consumption behavior through the installation of smart meters. Similarly, Duong (2023) investigated energy-saving behaviors among students in Vietnam, finding strong correlations between perceived behavioral control and positive attitudes towards energy savings. These studies highlight the importance of internal motivations such as awareness and responsibility as well as external influences like media publicity and group interactions. Other research has shown that perceived behavioral control significantly impacts residents' use of energy-efficient appliances (Harun, 2022) and purchasing behaviors related to energy efficiency (Yusliza et al., 2020). Liobikienė et al. (2021) emphasized that subjective norms related to environmental concerns positively influence residents' intentions to utilize renewable energy sources.

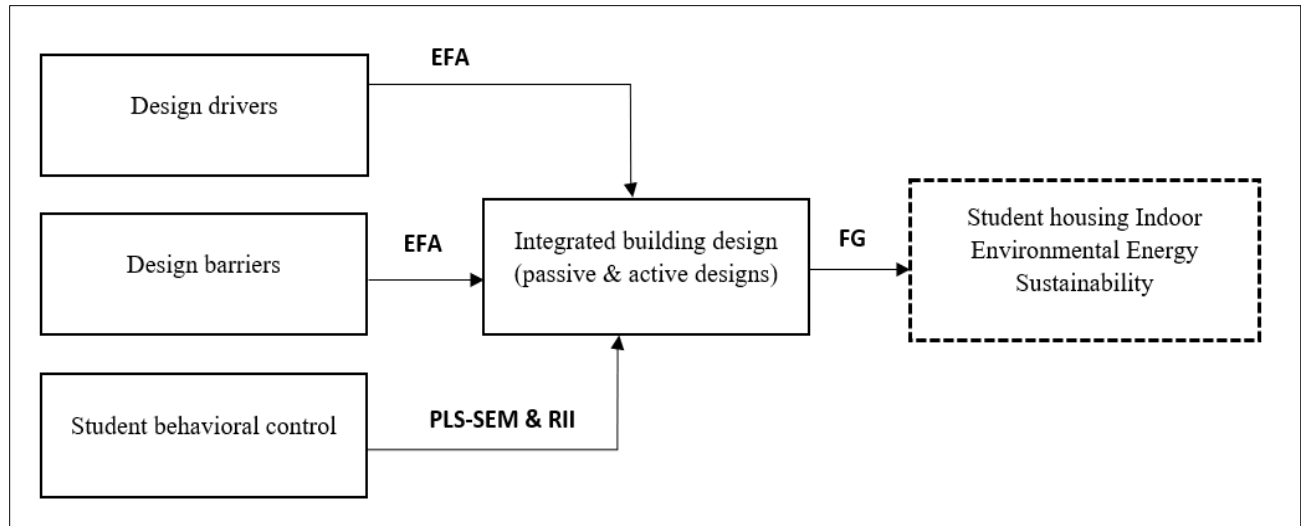


Figure 4.1 Conceptual framework of the study

Authors Construct: (2024)

4.7 Summary of chapter

The chapter presents empirical findings related to integrated building design, the drivers and barriers influencing sustainable practices, behavioral control, and the frameworks pertinent to the study. The integrated empirical review encompasses various aspects such as building envelope, orientation, circulation areas, window glazing, and other design elements that significantly impact energy sustainability. Key drivers identified for sustainable building design include aesthetics, reduction in energy consumption, knowledge drivers, inclusivity, social factors, the emergence of both passive and active design requirements, and supportive government policies. Barriers to sustainable building design have been observed as well, including issues related to the standardization of building materials, financial constraints, social dynamics, regulatory challenges, enforcement concerns, and knowledge gaps. Emerging factors influencing occupants' behavioral control include behavioral intentions, norms, attitudes, cultural beliefs, as well as physical and contextual parameters. This review highlights the diverse impacts on energy sustainability,

particularly in the Global North. However, there remains a gap in understanding how these parameters apply specifically to student housing in Sub-Saharan Africa. By assessing these critical areas through the proposed model in Figure 3, this study aims to provide actionable insights for designers, contractors, institutions, and housing managers focused on enhancing energy sustainability within the student housing sector. The Theory of Planned Behavior (TPB) serves as a foundational framework for this analysis. It posits that human behavior is influenced by three independent determinants: attitudes towards behavior, subjective norms reflecting perceived social pressures, and perceived behavioral control (Ajzen, 2011). This framework has been effectively applied in various studies related to building management and energy consumption. For instance, Zulu et al. (2022) found that subjective norms significantly influence household intentions to adopt solar energy. Similarly, Duong (2023) highlighted the importance of perceived behavioral control in shaping energy-saving behaviors among students in Vietnam. These findings underscore the relevance of internal motivations—such as awareness and responsibility—as well as external influences like media publicity and group interactions

CHAPTER FIVE

RESEARCH METHODOLOGY

5.1 Introduction

This chapter describes the methodological approaches employed to achieve the study's aim and objectives. The methodology is organized into three main parts. The first part addresses the research philosophical underpinning, which establishes the foundational beliefs and assumptions guiding the study. This philosophical framework is crucial for understanding how knowledge is constructed and how research questions are approached. The second part encompasses the research methodology, detailing the techniques used for data collection and analysis. This includes a discussion of sampling techniques, which specify how participants were selected, and the overall research design that frames the study's structure and approach. The final part focuses on methodological procedures and data analytical techniques. This section elaborates on the specific steps taken to gather data, such as surveys or interviews, and the analytical methods employed to interpret the data, including statistical analyses or qualitative assessments. By organizing the methodology in this manner, the study seeks to provide a comprehensive understanding of how these components work together to address the research objectives and research questions effectively.

5.2 Research philosophy

The philosophy of research encompasses the regulation, establishment, and systematic analysis of inquiry methods across various academic fields. Kamal (2019) describes philosophy as the foundational worldviews and strategies that influence research approaches. This philosophical standpoint is rooted in beliefs about the nature of reality and the study's context. Understanding these philosophical worldviews helps to shape researchers' positions regarding The chosen

methodologies. Creswell (2009) asserts that selecting a research methodology is inherently linked to these philosophical underpinnings. Philosophical positions allow for inclusivity, tolerance, and expansion within research methodologies, suggesting that defending a research question and methodology without grounding it in philosophical principles would be inadequate. Scholars have identified epistemology and ontology as two primary philosophical considerations in both physical and social research.

5.2.1 Ontological assumption

Ontological assumptions in research relate to the fundamental nature of reality that are crucial in understanding the phenomena under investigation. They examine whether societal beliefs are intrinsic and unchanging or shaped by people's actions and perceptions (Al-Ababneh, 2020). Scholars often associate these assumptions with two conflicting perspectives: constructivism and objectivism (MacLeod et al., 2022). According to MacLeod et al. (2022), constructivism views social phenomena as constantly evolving, influenced by the social interactions of individuals. In contrast, objectivism argues that social phenomena exist independently of human influence, as external realities beyond the control of social actors (Schneider, 2022).

Researchers further explore ontological assumptions through a set of guiding questions. These include: (1) Are all activities on earth reducible to mechanical motions? (2) Is there a higher intelligence within or beyond the universe? (3) Are physical bodies or objects the most significant entities, while abstract forms are less relevant? (4) Are communities independently real, or is individual existence paramount? (5) Are universal terms rooted in real entities (Stevens, 2020)? These questions highlight the connections between the investigation of social and natural phenomena, providing a framework for understanding the nature of sustainable student housing design in Ghana. Specifically, the ontological position of the study is based on the realist's

perspective which focuses on understanding that sustainable student housing design is measured based on its ability to provide indoor environmental quality, energy efficiency, reduce cost, and protect the environment.

5.2.2 Epistemological assumption

Epistemological assumptions relate to questions about what is considered valid knowledge within a particular field (Willig, 2019). According to Willig (2019), these assumptions help us understand how the social world serves as a means of conveying knowledge to others. Epistemological assumptions can be categorized into several types: Empiricism, which explores human senses and how knowledge is acquired, utilized, and developed; Rationalism, which holds that knowledge comes from a direct examination of human thought processes (Al-Ababneh, 2020); Falsificationism, which suggests that knowledge is shaped through trial and error by testing theories against empirical evidence; and Neo-realism, which asserts that knowledge is based on the mechanisms and structures that generate it. Abou Samra (2021) reorganizes these assumptions into two key perspectives: first, whether knowledge is something that must be individually acquired, and second, whether it must be personally experienced. The first perspective is known as positivism, which supports the use of natural science to study social reality (Abou Samra, 2021), while the second is referred to as interpretivism. The epistemological view of the study is based on the assumption of not relying on the technical and environmental perspective in isolation, but, the inclusion of the behavioural aspect of energy users that influences student housing design and implementation. This leads to the discussion of philosophical approaches in the following section.

5.3 Philosophical paradigm

Research philosophical paradigms such as pragmatism, positivism, interpretivism, post-positivism, critical realism, and postmodernism form the foundation of many research studies

(Kamal et al., 2019). Among these paradigms, positivism, interpretivism, and pragmatism have been extensively applied in disciplines like physical science, including construction management.

The pragmatism paradigm is based on practicality—focusing on what works and is being practiced. It emphasizes the use of research methods that address the research problem, regardless of whether they are qualitative or quantitative. Pragmatism considers both subjective and objective knowledge in achieving research objectives. As Creswell (2007) points out, the pragmatist is free to select any research strategy that best answers the research questions, leading to a flexible approach that might combine both quantitative and qualitative methods.

The interpretivism paradigm, as explained by Sciberras and Dingli (2023), posits that reality, meaning, and knowledge are derived from individual interpretations. Scholars debate various aspects of interpretivism, but they all emphasize subjective understandings of how people perceive and make sense of events and the societal impacts. Interpretivist researchers commonly use qualitative tools such as participant observation, interviews, and focus group discussions to draw inductive conclusions and develop deeper understandings of the phenomena they investigate (Elliott & Timulak, 2021).

The positivism paradigm asserts that only knowledge verifiable by the intellect is considered valid knowledge (Clark et al., 2021). This paradigm emphasizes empirically certifiable facts, primarily using quantitative methods. According to Karupiah (2022); and Clark & Bryman (2019), positivism favors scientific statements that can easily confirm realities over normative statements based on the senses. It views the world objectively and investigates relationships among variables through hypothesis testing and the generalization of results, typically using structured sampling techniques (Clark & Bryman, 2019).

On the other hand, Postmodernism, focuses on the idea that reality is socially built through power dynamics and complex relationships. It emphasizes dominant perspectives on what constitutes truth and knowledge (Creswell, 2007). The postmodernist approach often uses deconstructive methods, involving in-depth investigations of phenomena through qualitative techniques, such as textual analysis, without relying on broad datasets.

These different philosophical paradigms influence how researchers approach The studies, shaping The research approaches and analysis depending on the type of research questions and objectives.

5.3.1 Philosophical position of the study

This research employs a pragmatist philosophical framework, which is particularly suitable for assessing the impact of building design implementation on the sustainability of indoor environmental energy. The pragmatist approach is relevant for its extensive use of both qualitative and quantitative methodologies when developing a comprehensive framework within the environmental sustainability context. From an epistemological perspective, the study focuses on identifying the barriers and drivers influencing design implementation, as highlighted by Al-Ababneh (2020). More specifically, it situates the behavioral control of students regarding indoor environmental energy sustainability within the frameworks of Falsificationism and neorealism, which serve to critically examine underlying epistemological challenges. The pragmatist worldview emphasizes the necessity of investigating problems, such as the high energy consumption and inadequate building designs affecting energy sustainability in student housing. This perspective suggests that exploring the requirements, drivers, barriers, and behavioral aspects from various stakeholders—including architects, student housing managers, investors, energy experts, and students—will lead to effective and practical solutions for enhancing sustainability in

student housing. Achieving this goal necessitates a well-adapted research design, which will be elaborated upon in the following section detailing the methodological stance of this study.

5.4 Research methodology

Research methods represent a systematic and organized approach to investigating specific research questions within a study. According to Bryman (2016), researchers conducting empirical studies have three fundamental options regarding research methods such as qualitative, quantitative, and mixed. The qualitative research strategy focuses on narrative data and sources, emphasizing a value-laden inquiry that is subjectivist, relativist, and deductive in nature when addressing societal issues. Analytical strategies associated with this method include narrative inquiry, grounded theory, action research, and ethnography. In contrast, quantitative research methods utilize numerical data, employing statistical and mathematical tools for analysis (Creswell, 2007). This approach stems from objectivist, realist, inductive frameworks that aim to study societal problems in a value-free manner. The third methodological strategy is the mixed methods approach. This method combines both quantitative and qualitative data and techniques to investigate societal issues (Bryman, 2016). This method aligns with the abductive approach, designed to mitigate the limitations inherent in both inductive and deductive reasoning found in qualitative and quantitative research. The abductive approach is rooted in pragmatism, facilitating the construction of theories and logical inferences about complex phenomena.

Creswell (2007) highlights the relevance of mixed methods for gaining wide-ranging understanding of the depth and breadth of research problems. Many scholars argue that integrating the quantitative and qualitative methodologies can improve the robustness of research findings; thus, quantitative methods can address the weaknesses of qualitative approaches and vice versa (Bryman, 2016). Mixed methods can be categorized into three strategies as outlined by Ngulube

(2021): triangulation, which involves using quantitative research to support qualitative findings or the reverse; facilitation, where one methodology bolsters findings derived from another; and complementary, which merges two distinct methodologies to explore a research problem comprehensively.

5.4.1 Justification of research method of the study

The adoption of a pragmatic philosophical framework in this study necessitates the implementation of mixed methods. This approach was chosen due to its ability to provide a comprehensive and balanced research strategy that addresses the limitations inherent in studies based on either quantitative or qualitative methodologies (Timans et al., 2019). By integrating narratives from architects, investors, student housing managers, energy experts, and students regarding the implications of building design on indoor environmental energy sustainability, the study aims to enhance the quantitative findings related to sustainability impacts across student housing in Ghana. Research has shown that combining qualitative and quantitative research techniques offer a strong understanding of research phenomena that cannot be fully captured through either approach alone (Hafsa, 2019; Ngulube, 2021). Furthermore, mixed methods facilitate the integration of various data sources to tackle complex issues (Hafsa, 2019).

The specific context of Ghana will allow for a thorough exploration of building design strategies aimed at promoting indoor environmental energy sustainability, enabling findings to be generalized across purpose-built student housing. The methodology employed involves collecting both open-ended semi-structured data and closed-ended questionnaire data, which together support the objectives of this mixed-methods approach.

5.5 Research design strategies

Research design outlines the comprehensive process of conducting research, encompassing everything from the initial stages to data analysis. It serves as a blueprint for achieving the research objectives. Creswell characterizes research design as a strategic plan for executing research (Creswell, 2003). Singh (2019) emphasizes that the philosophical foundations and strategies inform the thinking behind research design. In alignment with the study's objectives, a pragmatism interpretive framework was adopted, employing a mixed-methods approach. Scholars have identified three primary mixed-method designs: Convergent Parallel Mixed-Methods Research Design, Exploratory Mixed-Methods Design, and Explanatory Sequential Mixed-Methods Design (Dawadi et al., 2021; Vebrianto et al., 2020).

The Convergent Parallel Mixed-Methods Design adheres to a pragmatist theoretical paradigm, integrating quantitative and qualitative methods to yield triangulated findings. This design necessitates the simultaneous collection of two datasets, which are then analyzed independently using qualitative and quantitative strategies (Dawadi et al., 2021). The significance of this design is based on its ability to provide a comprehensive understanding of the distinct findings from both quantitative and qualitative data, offering a fuller picture of the phenomenon under investigation. Conversely, the Explanatory Sequential Mixed-Methods Research Design unfolds in two interactive stages (Vebrianto et al., 2020). Initially, quantitative data is collected and analyzed to establish preliminary findings. Subsequently, qualitative research is designed based on these quantitative results. This follow-up aims to deepen the understanding of specific quantitative outcomes through interviews and qualitative insights. The Exploratory Sequential Design is characterized as a qualitative three-phase study that aligns with constructivist philosophical thinking. The first phase involves an in-depth exploration of issues, followed by classification and

measurement of variables in the second phase. The final phase entails collecting quantitative data to identify statistical patterns, which are then generalized alongside qualitative findings. For this study's objectives, the Explanatory Sequential Mixed-Methods Design was selected. The subsequent section will justify this design choice.

5.5.1 Research design of the study

The study employed an explanatory sequential mixed research design based on complementary mix approaches. This methodology integrates qualitative data to enhance and clarify quantitative findings. While this approach may require significant time investment, it is instrumental in providing a comprehensive understanding of indoor environmental energy sustainability within student housing in Ghana. The research was structured into five distinct processes. The first process involved identifying the research problem, followed by a thorough literature review in the second stage. The third stage focused on methodology, utilizing two approaches. The initial approach involved the concurrent collection of both quantitative and qualitative data from various stakeholders, including architects, student housing managers, student housing investors, energy experts, and student leaders residing in the residential buildings. The second approach involved separating the two datasets, where qualitative data were employed to elucidate the predictors of variables derived from the quantitative findings. The final stages of the study encompassed the results and discussions, integrating different methods and analytical approaches tailored to each objective based on a comprehensive literature review.

1. The first objective aimed to assess critical design requirements in student housing and the impact on indoor environmental sustainability in Ghana. Here, both qualitative and quantitative methods were utilized to collect and analyze data related to sustainable student housing design requirements.

2. The second objective sought to identify the drivers of sustainable student housing design in Ghana through surveys conducted with student housing investors and architects. This objective employed both quantitative and qualitative techniques to ascertain the factors driving the adoption of sustainable designs.
3. Similarly, the third objective utilized both quantitative and qualitative data collection and analysis methods to explore barriers to sustainable student housing designs in Ghana.
4. The fourth objective focused on understanding the behavioral control of student housing users and its effects on energy consumption in Ghana, relying solely on quantitative techniques for this analysis.
5. Finally, the fifth objective aimed to develop a framework for assessing sustainability in student housing designs within Ghana.

This structured approach allows for a nuanced investigation of the factors influencing indoor environmental energy sustainability in student housing, thereby contributing valuable insights relevant to future practices and policies in this area. Figure 5.1 shows the research design workflow

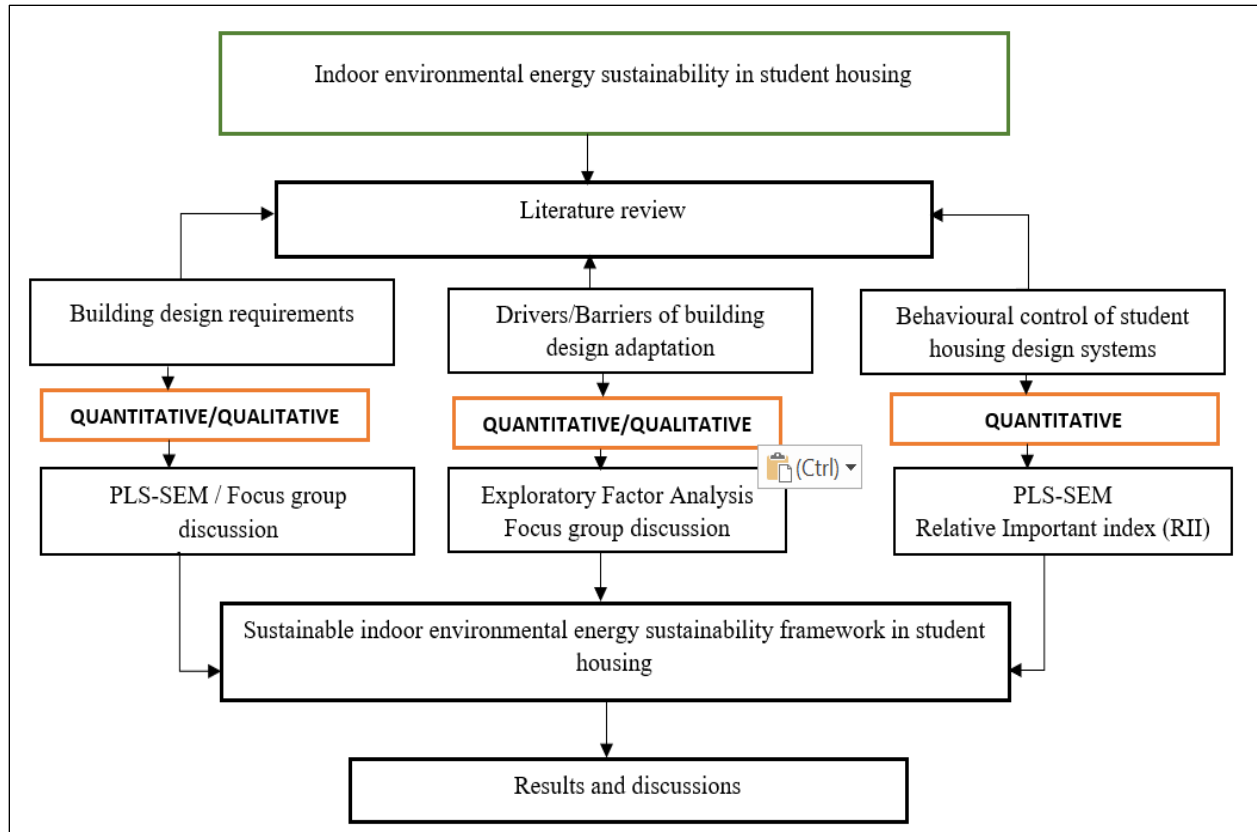


Figure 5.1 research design workflow

Source: Author's construct (2024)

5.6 Research design matrix

The research design matrix provides a detail explanation of how the study was conducted (see Table 5.1). The matrix includes the research objectives, questions, mode of data collection, techniques of analysis, and expected results.

Table 5.1 Research design matrix of the study.

Research objective	Research questions	Mode of data collection	Mode of data analysis
To examine design requirements and its influences on indoor environmental energy sustainability in student housing in Ghana	What are the critical design requirements in student housing towards indoor environmental energy sustainability?	Survey	
	How does building design influence indoor heating and cooling in student housing	Survey Focus group discussion	PLS-SEM Thematic analysis
To identify the drivers of adopting sustainable student housing design in Ghana	What are the key factors of adaptation of sustainable student housing design and implementation in Ghana?	Survey Survey Focus group discussion	Exploratory Factor Analysis Thematic analysis
To assess the barriers of adopting sustainable student housing design in Ghana	What critical barriers of adaptation of indoor environmental energy sustainability designs among student housing in Ghana?	Survey Survey Focus group discussion	Relative Important Index Thematic analysis
To assess students' behavioral control of student housing design systems towards indoor environmental energy sustainability in Ghanaian student housing	What student attitude of building control systems influence indoor environmental energy sustainability in Ghana?	Survey	Exploratory Factor Analysis
	What is the relationship between students' interactions with building controls and its effects on energy consumption and indoor environment?	Survey	PLS-SEM
To develop sustainable design framework towards indoor environmental sustainability in student housing	How does compliance and noncompliance of building design influence indoor environmental energy sustainability in student housing	Focus group discussion	Thematic analysis
	What critical drivers influence compliance and noncompliance of building design in indoor environmental energy sustainability in student housing	Focus group discussion	Thematic analysis

Source: Author's Construct (2024)

5.7 Source Data Collection

Sources of data collection include both primary and secondary data. Primary data on student housing design requirements were collected from professional and licensed Architect of student housing across the study locations. Using close-ended survey questionnaire drivers and barriers of sustainable building design were also be collected from architects, student housing leaders, student housing managers, and student housing investors.

Secondary data for this study includes annual energy consumption receipts from student housing managers as part to determine the impact of sustainable building design requirements on energy consumption among the student housing.

5.8 Tools of data collection

The study relied on close-ended questionnaire survey and interview guide for focus group discussion.

5.8.1 Questionnaire survey

Questionnaire surveys consist of a series of both closed and open-ended questions, facilitating multiple interactions with participants involved in the study (Bihi, 2021). This method is widely recognized for its efficiency and cost-effectiveness in data collection, making it a popular technique in social science research. Questionnaire surveys have been extensively utilized to investigate energy use behaviors in various energy studies (Hafez et al., 2023; Wang et al., 2023; Zhang et al., 2024).

In this study, this technique was employed to explore the requirements, drivers, barriers, and behavioral controls related to energy use in Ghanaian's student housing through structured questions. The implementation of the questionnaire survey involved several key steps. Initially,

the preamble of the instrument was defined, followed by identifying the experts responsible for conducting each survey. The third step included piloting the instrument at Simon Deidon Dombo University of Business and Integrated Development Studies in Wa. Finally, data collection was carried out using the Kobo Collect application. The questionnaire was structured into three distinct parts. The first part focused on identifying the drivers and effects of sustainable student housing requirements on energy consumption, specifically targeting professional architects. The second part addressed the drivers and barriers of sustainable student housing design from the perspective of investors. The third part examined awareness, consumption patterns, and energy use behaviors among student housing managers in Ghana. Additionally, this section included questions aimed at understanding the drivers of energy use behaviors from the perspective of student leadership. This comprehensive approach to questionnaire design ensures that diverse viewpoints are captured, providing valuable insights into energy sustainability within student housing contexts.

5.8.2 Focus group discussion

Focus group discussions involve indirect interviews through collaborative dialogues with research participants, enabling the generation of diverse data sets. This technique has been effectively utilized in energy-related studies that examine energy consumption and sustainability (Dey et al., 2022; Godin et al., 2020; Cole, 2019). According to Sim and Waterfield (2019), focus group discussions should begin with a consent process, followed by a briefing, the actual discussion, debriefing, and drawing conclusions.

In this study, focus group discussions were employed to investigate the requirements of student housing design, as well as the drivers and barriers associated with sustainable student housing from the perspective of experts. The process commenced with drafting a consent letter addressed to the University of Energy and Renewable Natural Resources and the Ghana Energy Commission.

Subsequently, a copy of the interview guide was shared with them for preliminary review. During the group session, a system of deductive disclosure was implemented using codes (e.g., FG1) to represent respondents while preserving the anonymity. A professor specializing in renewable energy facilitated the discussion. The session began with questions directed at the experts to stimulate dialogue, ultimately leading to a consensus on the key requirements, drivers, and barriers related to sustainable student housing in Ghana based on the rankings. Experts were also encouraged to seek clarification as needed during the conclusion phase. This structured approach not only fosters an inclusive environment for expert opinions but also enriches the data collected on sustainable student housing design by capturing varied insights and experiences from multiple

5.9 Sampling procedure

Sampling refers to the process of selecting research participants from a larger population using specific research techniques (Rahman, 2023). In this study, both purposive and convenient sampling methods were employed. Convenient sampling has been efficiently used in similar studies (Yi-Fang et al., 2022; Lee & Hussain, 2023). The purposive sampling approach is widely recognized as a qualitative technique that relies on expert opinions (Andrade, 2021). Thomas (2022) notes that homogeneous purposive sampling is particularly useful for examining populations with similar characteristics. Consequently, this method was utilized to sample energy experts, student housing investors, architects, and student housing managers in order to gain insights into the perceptions regarding the necessary requirements for achieving indoor environmental energy sustainability in university housing in Ghana. Architects and energy experts were determined based on the experiences on projects related to energy efficiency and sustainability in residential buildings, particularly related to educational institutions. Also, Student

housing investors and managers were purposively selected because they have an idea on the financial contributions of adopting sustainable student housing design.

The convenient sampling was used to select student housing leaders to understand the energy use behaviour, drivers of indoor energy consumption, and building control features that influences student's energy consumption. By combining these two sampling techniques, the research effectively captured a comprehensive view of the factors influencing energy sustainability in student housing, facilitating a robust analysis of the collected data.

5.10 Sample size determination

Sample size defines the proportion of a population selected with sufficient information that can be used to generalize the findings of a research (Rahman, 2023). This section describes the sample size of university student housing, student housing investors, student housing leaders, professional architects, student housing managers, and energy experts.

5.10.1 Student housing selection

The study's sampling procedure involved selecting all on-campus student housing from public universities and technical universities across both Southern and Northern Ghana. A total of six universities were purposively chosen from fourteen in Southern Ghana, including Kwame Nkrumah University of Science and Technology, University of Cape Coast, University of Education Winneba, Takoradi Technical University, Kumasi Technical University, and Sunyani Technical University. In Northern Ghana, five universities were selected: The University for Development Studies in Tamale, Simon Diedon Dombo University of Business and Integrated Development Studies in Wa, Tamale Technical University, Bolgatanga Technical University, and CK. T. University of Technology and Applied Sciences (see Table 5.2).

The selection criteria for these universities included high student enrollments, significant investment in student housing, and the availability of purpose-built student accommodations. Participant observation was employed to select on-campus housing based on compliance and non-compliance with building requirements. In this context, "on-campus" refers to both public and private student housing located within university premises. Using a purposive sampling method, all public on-campus student housing was included in the study. This comprehensive sampling strategy ensures that a representative range of perspectives is captured regarding the factors influencing indoor environmental energy sustainability in student housing across Ghana.

Table 5.2 statistics of on-campus student housing in Ghana

Name of university	On-campus University purpose-built student housing	On-campus private purpose-built student housing	Total
Southern Ghana Universities			
Sunyani Technical University	3	3	6
University of Cape Coast	5	6	11
Takoradi Technical University	3	2	5
Kwame Nkrumah University of Science and Technology	5	4	9
Kumasi Technical University	3	2	5
University of Education, Winneba	3	1	4
TOTAL	22	18	40
Northern Ghana Universities			
University for Development studies	3	4	7
CK. T. University of Technology and Applied Sciences	4	5	9
Tamale Technical University	2	3	5
Bolgatanga Technical University	2	2	4
TOTAL	11	14	25

Source: Field survey (2024)

5.10.2 Selection of student housing leaders

This section outlines the sampling procedure and size for student housing leaders involved in the study. A total of 222 student housing leaders were selected from Southern Ghana, while 120 were chosen from Northern Ghana (see Table 5.3). These individuals were selected based on the experience in interacting with students and the role in managing student housing behaviors as leaders. Importantly, the selection process was designed to be free from gender bias, as indicated by data collected from student housing managers and Deans of Students across various campuses. Table 5.3 provides a detailed breakdown of the sample size of student housing leaders in Ghana. This approach ensures a diverse representation of perspectives among student housing leaders, contributing to a comprehensive understanding of the factors influencing energy sustainability in student housing contexts.

Table 5.3 Survey of student housing leaders

Name of university	On-campus purpose-built housing leaders	University student	On-campus purpose-built housing leaders	private student	Total student housing leaders
Southern Ghana Universities					
	Total housing	Total leaders	Total housing	Total leaders	
Sunyani Technical University	3	18	3	12	30
University of Cape Coast	5	30	6	30	60
Takoradi Technical University	3	18	2	12	30
Kwame Nkrumah University of Science and Technology	5	30	4	24	54
Kumasi Technical University	3	18	2	6	24
University of Education, Winneba	3	18	1	6	24
TOTAL	22	132	18	90	222
Northern Ghana Universities					

University for Development studies	3	18	4	20	38
CK. T. University of Technology and Applied Sciences	4	17	5	19	36
Tamale Technical University	2	12	3	14	26
Bolgatanga Technical University	2	11	2	9	20
TOTAL	11	58	14	62	120

(source: field survey, 2024)

5.10.3 Selection of Professional Architects

This section describes the sampling procedure and size of architect for the study. Following 2023 annual report on registered architects on good standing, a sample frame of 534 was drawn.

Adopting the Yamane (1967) formula for sample size determination

$$n = \frac{N}{1 + N(e^2)}$$

where N represents the population size for the study, n is the sample size required, and e is the level of precision adopted (error limit). For this study, this is taken as $\pm 5\%$. Therefore:

Calculating sample size:

$$n = \frac{534}{\{1 + 534(0.05^2)\}}$$

$$n = 224$$

Based on the analysis, 224 professional architects were sampled.

5.10.4 Selection of student housing managers and investors

This section outlines the sample size of student housing investors and student housing managers in Ghana. Based on data obtained from Deans of Students across various campuses, the study

selected a total of 65 student housing investors, which includes 37 investors from universities in Southern Ghana and 28 from Northern Ghana (see Table 5.4). Additionally, the study encompassed 340 student housing managers, representing all managers from the different campuses. Specifically, there were 207 student housing managers in Southern Ghana and 133 in the Northern region. The student housing managers were defined to include various roles such as facilities managers, tutors, technical officers, electricians, and porters. This comprehensive sampling ensures a diverse range of insights into the factors influencing energy sustainability in student housing across Ghana.

Table 5.4 Survey of student housing managers

Name of university	On-campus purpose-built housing	University student	On-campus purpose-built housing	private student	Total student housing managers
Southern Ghana					
	Total housing	Total managers	Total housing	Total managers	
Sunyani Technical University	3	18	3	12	30
University of Cape Coast	5	30	6	25	55
Takoradi Technical University	3	18	2	12	30
Kwame Nkrumah University of Science and Technology	5	30	4	16	46
Kumasi Technical University	3	18	2	4	22
University of Education, Winneba	3	18	1	6	24
TOTAL	22	132	18	75	207
Northern Ghana Universities					
University for Development studies	3	15	4	24	39
CK. T. University of Technology and Applied Sciences	4	24	5	25	49

Tamale Technical University	2	10	3	15	25
Bolgatanga Technical University	2	8	2	12	20
TOTAL	14	57	14	76	133

Source: Field survey (2024)

5.11 Selection of Energy Experts

This section details the sample size of energy experts involved in the study. According to Guest et al. (2006), an effective sample size for conducting focus group discussions typically ranges from 6 to 12 participants, which is adequate for reaching saturation of responses (Hamilton & Finley, 2019). Based on this guideline, a sample of 10 energy experts was selected from the University of Energy and Renewable Natural Resources to participate in the focus group discussion. The selection criteria focused on expertise in areas such as renewable energy consumption, electrical and mechanical engineering, and residential energy systems. This group included one professor, six senior lecturers, and three technicians. Additionally, one energy expert was chosen from the Ghana Energy Commission to provide insights into energy use regulations and renewable energy policies relevant to the student housing market in Ghana. This structured approach ensures a diverse range of expert opinions, contributing valuable insights into the factors influencing energy sustainability in student housing contexts.

5.12 Piloting survey of the study

This section outlines the approach taken to pilot the research instruments for the study. According to Malmqvist et al. (2019), piloting research instruments is commonly employed in quantitative inquiry disciplines such as physical sciences, medicine, and nursing. In social sciences, feasibility studies and pre-testing are the predominant forms of piloting (Malmqvist et al., 2019). For this study, piloting was conducted at Simon Diedon Dombo University of Business and Integrated

Development Studies, a newly established institution that emerged from the former University for Development Studies, Wa campus. Given its new student housing facilities and relevant departments—including Construction Studies, Real Estate, and Works and Municipal Services—this university was deemed suitable for the pilot study. During the piloting process, seasoned experts in construction management, facilities management researchers, architects with expertise in sustainability, and indigenous building design were selected from these departments.

A total of 10 experts participated in examining the research instruments focused on student housing design requirements and energy consumption. Additionally, 8 university student housing tutors and hall masters from four residential halls, along with 8 student housing leaders, were chosen to review the instrument related to student behavioral control and energy use within the residential halls. Finally, 5 on-campus student housing investors were included to assess the drivers and barriers associated with adopting sustainable student housing in Ghana. The pre-testing revealed some minor grammatical errors and punctuation issues. The entire piloting process spanned two weeks across both sessions, ensuring that the research instruments were refined for clarity and effectiveness before the main study commenced. This thorough approach to piloting enhances the reliability of the data collection tools used in the research.

5.13 Ethical consideration

The ethical considerations in this study involved two key processes. First, an informed consent letter was sent to gatekeepers, including the Deans of Students' offices across the study locations, the Architects Council of Ghana, the Ghana Energy Commission, and the University of Energy and Renewable Natural Resources. This letter outlined the aims of the research. Second, the elected participants were guaranteed of data secrecy, emphasizing that the data collected would be used solely for academic purposes. To ensure confidentiality, it was highlighted that the interests,

opinions, and identities of respondents would be protected. Participants were also informed that they would not be compelled to respond to the questionnaires; instead, the participation was voluntary. This ethical framework is essential for fostering trust and ensuring that participants feel secure in sharing the insights, eventually supporting the integrity and validity of the research findings.

5.14 Methodological analytical approaches

5.14.1 Exploratory Factor Analysis

Exploratory Factor Analysis (EFA) is a quantitative statistical tool widely used in psychology to uncover the fundamental drivers of phenomena based on questionnaire survey data. This method employs a data-driven approach that operates under a common factor model. In EFA, observed variables are conceptualized as weighted sums of potentially correlated drivers or unique individual drivers. The differences among these common drivers determines covariances among the observed variables, which are central to the study's focus. EFA is described as a multivariate statistical procedure aimed at identifying the fewest hypothetical drivers, internal attributes, latent factors, and dimensions that can effectively explain the covariation among observed factors. The application of EFA traces back to Spearman (1904), who utilized it to validate theories. Since then, EFA has been extensively employed to explore relationships between variables and indicators of unobserved human behavior.

In energy studies, for instance, Ahiabu et al. (2022) utilized EFA to identify barriers to adopting sustainable building designs. Similarly, Afful et al. (2022) and Adabre et al. (2022) employed EFA for assessing obstacles to sustainable designs, while Khajavi et al. (2021) used it to evaluate drivers of energy efficiency in integrated building designs. Du and Pan (2020) also applied EFA to investigate behavioral intentions regarding energy consumption. Effectively implementing EFA

involves several key processes, including defining variables, selecting participants, ensuring data appropriateness, and establishing model definitions. This structured approach allows researchers to derive meaningful insights from complex datasets, contributing significantly to understanding various phenomena in fields such as energy consumption and sustainability.

5.14.1.1 Definition and measurement of variables of EFA

The definition of variables in Exploratory Factor Analysis (EFA) is crucial, as it ensures that the factors being examined are relevant and related to the study's focus, avoiding the inclusion of unrelated factors. Inadequate definitions may hinder the identification of significant common factors. For effective measurement, at least three measured variables are necessary to identify a common factor, and EFA performs optimally when multiple measured variables are influenced by that factor. Taherdoost (2019) has utilized various Likert scales to measure variables effectively, while Shrestha (2021) cautions against including interdependent variables in EFA analyses. Consequently, this study used a five-point Likert scale to assess common building design requirements, drivers, and barriers associated with sustainable student housing. This structured approach to variable definition and measurement is essential for accurately capturing the underlying constructs and ensuring the reliability of the EFA results. By carefully selecting and defining variables, the study seeks to uncover meaningful understanding of the drivers and barriers of adopting sustainable student housing design in Ghana.

5.14.1.2 Participants and appropriateness of EFA data

The selection of participants for Exploratory Factor Analysis (EFA) studies has been a topic of debate. Auerswald and Moshagen (2019) emphasize the importance of careful consideration in sampling when employing the EFA method. Child (2006) cautions against using samples from different populations, as this can skew results. The discussion surrounding the appropriate ratio of

variables to sample size often centers around a 10:1 or 5:1 ratio, with some scholars suggesting that fewer variables may require a smaller sample size, and vice versa. Fabrigar et al. (1999) argue that an adequate sample size is dependent on the strength, number, and relationships among the measured variables. The appropriateness of data for EFA hinges on the correlation among variables.

Hair et al. (2010) assert that factor analysis is justified when there is sufficient evidence of intercorrelation among the measured variables, with an acceptable correlation rate being above ± 0.30 . The factorability of the correlation matrix is assessed using Bartlett's test of sphericity, which aims to produce significant chi-square values to validate the application of EFA (Bartlett, 1954). However, large sample sizes can make this test sensitive to insignificant abnormalities in data randomness.

5.14.2 Model of Factor Analysis

The model of analysis in Exploratory Factor Analysis (EFA) can be categorized into two main types: Common Factor Analysis (CFA) and Principal Component Analysis (PCA). PCA is utilized to analyze the overall correlation matrix and calculates linear combinations of the measured variables to explain the underlying factors. In this context, the measured variables influence the components of these factors. Conversely, CFA aims to decompose the overall variance of the measured variables into distinct variances that are common and unique. This separation results in a reduced correlation matrix, with measured variables positioned along the diagonal of the correlation matrix. Estimations in PCA can be divided into two methods: Maximum Likelihood (principal factors) and Ordinary Least Squares (OLS). PCA is often compared to OLS as an acceptable estimation method. The PCA method relies on preliminary communality approximations, which are iteratively refined until an optimal reduced correlation matrix is

achieved. Statistical simulations are deemed appropriate when the sample size exceeds 40, indicating strong multivariate normality (Shrestha, 2021). Compliance will be assessed using a five-point Likert scale, where 5 indicates "strongly comply" and 1 indicates "strongly do not comply." This approach aims to identify the drivers and barriers of sustainable student housing design in Ghana, specifically addressing Objective 2, Question 1, and Objective 3, Question 1. This structured analytical framework ensures that the research effectively captures the underlying factors influencing sustainable building design within student housing contexts, facilitating a deeper understanding of energy sustainability challenges and opportunities.

5.14.2.1 Drivers of sustainable student housing design in Ghana

The literature review identified nine interrelated drivers of sustainable building design in residential contexts, which include economic, social, policy, design, financial, health and comfort, knowledge, all-inclusive, and market-related drivers. To assess these factors influencing sustainable student housing design in Ghana, a five-point Likert scale was employed, with indicators defined as follows: 1-2 indicating "Very Low Factor," 3-4 as "Low Factor," 5-6 as "Neutral," 7-8 as "High Factor," and 9-10 as "Very High Factor" (see Table 5.5). Using the Principal Component Method of EFA, the study successfully identified critical drivers of sustainable building design among student housing managers in Ghana. The application of this framework allows for a nuanced understanding of how various drivers interact and influence sustainable practices within student housing. The findings are crucial for informing policies and practices aimed at enhancing energy sustainability in the context of student accommodations in Ghana. Table 5.5 illustrates the identified drivers of sustainable student housing design, providing a clear overview of the factors that stakeholders should consider to foster more sustainable living environments for students.

Table 1.5 Factors influence adaptation of student housing design and implementation

Variable	Indicators	Construct
Economic		
	Climate change	ED1
	Affordability of building design.	ED2
	The emergence of active and passive design e.g. Use of air conditioner	ED3
	Building energy efficiency	ED4
	Reduction in waste and water efficiency	ED5
Building designs		
	Building layout for student movements	BD1
	Aesthetics	BD2
	Desired space for studying	BD3
	Flexibility in the use of stairs and all-inclusiveness	BD4
Institutional/government policy drivers		
	Government policy on the adaptation of sustainable buildings	GD1
	student housing management on the adaptation of energy efficient	GD2
	Financial incentives and subsidies for using renewables	GD3
	Sustainable housing as part of climate action goal	GD4
Financial drivers		
	The high energy cost for students	FD1
	Energy sharing mechanism among tenants	FD2
	Desire to reduce energy consumption	FD3
	Life cycle cost	FD4
	Reduction in construction cost	FD5
Health, safety, and comfort drives		
	Thermal comfort e.g. Heating and cooling	HD1
	Visual Comfort e.g. Lighting design and natural lighting	HD2
	Comfortable indoor health	HD3
	Safety in the use of energy appliances	HD4
All-inclusiveness and social drivers		
	Indoor energy appliances effects on students with disability	AD1
	Collaborative studying indoor environment	AD2
	Disability quality of life (health and comfort	AD3
	Inclusivity and physical accessibility	AD4
	Student and investors awareness of sustainable housing	AD5
Market drivers		
	Emergence of sustainability in the student housing market	MD1
	Student housing owners' readiness to adopt to sustainable buildings	MD2

	Availability of financial options tailored for sustainable building materials	MD3
	Increasing awareness for environmentally friendly and energy efficient student housing	MD4
Knowledge/awareness drivers		
	Lack of know-how on sustainable student housing	KD1
	Innovations in use of sustainable building materials	KD2
	Ideas from previous research studies on sustainable students housing	KD3
	Replicability and knowledge sharing among student housing	KD4
Environmental drivers		
	Reduced air pollution through clean building materials	END1
	Ecosystem and biodiversity preservation	END2
	Promoting reuse and recycling of materials	END3

Source: Author's Construct (2024)

5.14.2.2 Barriers of sustainable student housing design in Ghana

This section describes the EFA approach to extract the critical barriers of sustainable student housing in Ghana. Taking recognizance of reviews from literature, the study relied on social, regulatory, financial, economic, environment, and knowledge/awareness as barriers of sustainable student housing design. Table 5.6 shows the indicators of the barriers of sustainable student housing design derived from the literature review.

Table 5.6 Factors influence adaptation of student housing design and implementation

Variable	Indicators	Construct
Social		
	Complexity of sustainable designs	SB1
	Long product lifecycles (buildings and materials)	SB2
	Technical challenges and material recovery	SB3
	Lack of standardization of sustainable student housing designs	SB4
	lack of student housing market demand for sustainable building design	SB5
Regulatory barrier		

	Lack of consistent regulatory framework	RB1
	Obstructing laws and regulations	RB2
	Low regularity requirements	RB3
	Lack of energy audit and assessment	RB4
Financial barrier		
	High upfront investment costs in purchase of sustainable building materials	FB1
	High building material prices	FB2
	Limited funding	FB3
	Long payback period and investment risks	FB4
Knowledge barrier	Lack of knowledge on profitability and cost of indoor sustainable student housing	KB1
	Inadequate appropriate skills for managing sustainable student housing design (e.g. communication, awareness, experience, negotiation, leadership, and lateral thinking)	KB2
	Lack of knowledge of environmental effects	KB3
	Knowledge about building lifecycle-efficient energy solutions and running cost	KB4
Economic		
	Climate change	EB1
	Affordability of building design.	EB2
	The effects of active and passive design e.g. Use of air conditioner	EB3
	Building energy efficiency	EB4
	Effects on waste and water efficiency	
Environmental barrier		
	Health risk	ENB1
	Environmental pollution	ENB2
	Effects on ecosystem	ENB3

Source: Author's Construct (2024)

5.14.2.2 Barriers of sustainable student housing design in Ghana

This section describes the EFA approach to extract the critical barriers of sustainable student housing in Ghana. Taking recognizance of reviews from literature, the study relied on social, regulatory, financial, economic, environment, and knowledge/awareness as barriers of sustainable student housing design. Table 5.7 shows the indicators of the barriers of sustainable student housing design derived from the literature review.

Table 5.7 variables and indicators of barriers of sustainable student housing

Variable	Indicators	Construct
Social		
	Complexity of sustainable designs	SB1
	Long product lifecycles (buildings and materials)	SB2
	Technical challenges and material recovery	SB3
	Lack of standardization of sustainable student housing designs	SB4
	lack of student housing market demand for sustainable building design	SB5
Regulatory barrier		
	Lack of consistent regulatory framework	RB1
	Obstructing laws and regulations	RB2
	Low regularity requirements	RB3
	Lack of energy audit and assessment	RB4
Financial barrier		
	High upfront investment costs in purchase of sustainable building materials	FB1
	High building material prices	FB2
	Limited funding	FB3
	Long payback period and investment risks	FB4
Knowledge barrier	Lack of knowledge on profitability and cost of indoor sustainable student housing	KB1
	Inadequate appropriate skills for managing sustainable student housing design (e.g. communication, awareness, experience, negotiation, leadership, and lateral thinking)	KB2
	Lack of knowledge of environmental effects	KB3
	Knowledge about building lifecycle-efficient energy solutions and running cost	KB4

Economic		
	Climate change	EB1
	Affordability of building design.	EB2
	The effects of active and passive design e.g. Use of air conditioner	EB3
	Building energy efficiency	EB4
	Effects on waste and water efficiency	
Environmental barrier		
	Health risk	ENB1
	Environmental pollution	ENB2
	Effects on ecosystem	ENB3

(source: Authors construct, 2024)

5.14.3 Structural Equation Modelling for Energy Sustainability

Structural Equation Modeling (SEM) is a powerful statistical technique used to explain the direct, indirect, and total impacts of interconnected variables. This model integrates factor analysis and regression, allowing researchers to specify, estimate, and evaluate a model represented in a path diagram that reflects hypothesized interrelations among variables (Hair et al., 2021). SEM is particularly relevant for developing or testing new theories, as it is based on the assumption of a fundamental mechanism connecting hypothetical covariance structures between paths of random variables (Sarstedt et al., 2021). When the variance derived from observed variables aligns with the constraints imposed by the hypotheses, the structural model is deemed acceptable. SEM employs both latent and observed variables. Latent variables are those that cannot be measured directly, while observed variables are indicators that can be measured through scale items in survey questionnaires. Two main types of SEM are grounded in theory: Partial Least Squares (PLS) and Covariance-Based Models. The PLS-SEM model treats variables as composite indicators that mutually explain the construct (Sarstedt et al., 2021). It is particularly useful when the research objective focuses on theory development and prediction. Given the complex nature of developing a framework for indoor energy sustainability, confirmatory parameters are necessary to regulate this aspect effectively. Therefore, this study utilized PLS-SEM based on its research objectives.

The procedures for conducting SEM involve several steps: model specification, identification, parameter identification, model fit testing, and potential re-specification of the model.

5.14.3.1 Definition of variables for model

This section addresses Objective 1, Question 2, and Objective 4, Question 3. For Objective 1, sustainable student housing requirements were assessed based on existing literature. A five-point Likert scale was utilized, with indicators defined as follows: 1-2 representing "Very Low Factor," 3-4 as "Low Factor," 5-6 as "Neutral," 7-8 as "High Factors," and 9-10 as "Very High Factors." The requirements evaluated included building envelope, building orientation, building design height, indoor circulation area, gross floor span, and window glazing efficiency (see Table 5.8). Additionally, the effects of these requirements on heating and cooling in student housing were analyzed. For Objective 4, Question 3, variables were categorized into physiological, contextual, physical, social, and psychological factors (see Table 5.8). These variables were assessed for their impact on energy consumption. The indicators for these variables were also measured using a five-point Likert scale, defined as: 1-2 indicating "Very Low Influence," 3-4 as "Low Influence," 5-6 as "Moderate Influence," 7-8 as "High Influence," and 9-10 as "Very High Influence" (see Table 5.8). This structured approach enables a comprehensive evaluation of the critical drivers influencing sustainable student housing design in Ghana while also examining the factors that affect energy consumption. The findings will provide valuable insights into enhancing energy sustainability in student housing contexts.

Table 5.8 Sustainable student housing requirements

Variable	Indicators	Construct
Building orientation		
	Related to Wind and Sun	BO1
	Related to building View	BO2
	Related to privacy	BO3
	Shielding from external noise	BO4

Building envelopes		
	Building Massing/ form	BE1
	Glazing requirements	BE2
	Nature of façade material	BE3
Design complexity and shape		
	Building design efficiency	DCS1
	Building shape complexities	DCS2
	Building environmental performance	DCS3
	Building compatibility of external environment	DCS4
Building design levels and height		
	Average building storey height	BDLH1
	Number of floor levels in building	BDLH2
	Building functionality and use	BDLH3
	Building accommodates vertical movement	BDLH4
Indoor circulation design		
	Circulation space in the building	ICD1
	Logical flow within rooms	ICD2
	Access to communal areas and exits	ICD3
	Efficient circulation routes and convenience	ICD4
Window design and glazing		
	Shape of window glazing	WDG1
	Efficiency of window glazing	WDG2
	Sun shading geometry	WDG3
	Ventilation and acoustic performance	WDG4
Gross indoor area span		
	Indoor floor dimension	GIAS1
	Size of usable areas	GIAS2
	Indoor space flexibility	GIAS3
	Proportion of circulation space	GIAS4
Heating and cooling		
	High heating	HC1
	Low cooling	HC2

Source: Author's Construct (2024)

5.14.3.2 Model specification and identification

This step involves translating concepts into a series of hypothetical equations represented in a path diagram. The path diagram reflects the conventional correlations and residual unexplained paths derived from the researcher's prior knowledge through relevant literature. In this diagram,

rectangles represent observable variables, while ovals denote unobservable variables. One-headed straight arrows illustrate unidirectional associations between variables, and error terms are also represented by rectangles. The diagram visually represents the hypothesized relationships among the defined latent variables in the study. Standardized coefficients are depicted on the paths to indicate the effects of latent variables. Model identification is based on observable covariance and variance. Over-identified models are preferred as they establish essential conditions where degrees of freedom exceed zero (Hair et al., 2019).

In this section, hypotheses were developed based on the literature reviewed. Figure 5.2 illustrates the model for Objective 1, while Figure 5.3 shows the model for Objective 4. The theory of planned behavior, developed by Icek Ajzen, serves as a foundational framework for understanding human behavior across various contexts (Ajzen, 2011). This theory posits that intentions to perform specific behaviors can be predicted with high accuracy based on perceived behavioral control, subjective norms, and attitudes (Bosnjak et al., 2020). The application of this theory in building management has garnered significant attention, with studies highlighting its relevance in assessing household intentions to adopt sustainable practices such as solar energy usage and energy-efficient appliances. Emerging studies confirm that drivers of sustainable building design include economic, social, technological, environmental, and governmental policy factors (Munaro et al., 2020; Chan & Anabre, 2019). However, specific drivers related to sustainable student housing have not been extensively explored. For instance, economic drivers encompass affordability, climate change considerations, aesthetics, and energy consumption reduction (Gharehbaghi et al., 2022; Mi et al., 2020). Financial drivers such as life cycle costs and commercial viability also play critical roles in decision-making around sustainable construction (Oke et al., 2024). Health and comfort drivers have been highlighted as key determinants of building performance but require further exploration

regarding the impact on energy sustainability (Tran & Huang, 2022). Knowledge drivers contribute to understanding innovations and gaps in energy sustainability but have not been fully assessed in terms of the influence on actual energy use behaviors.

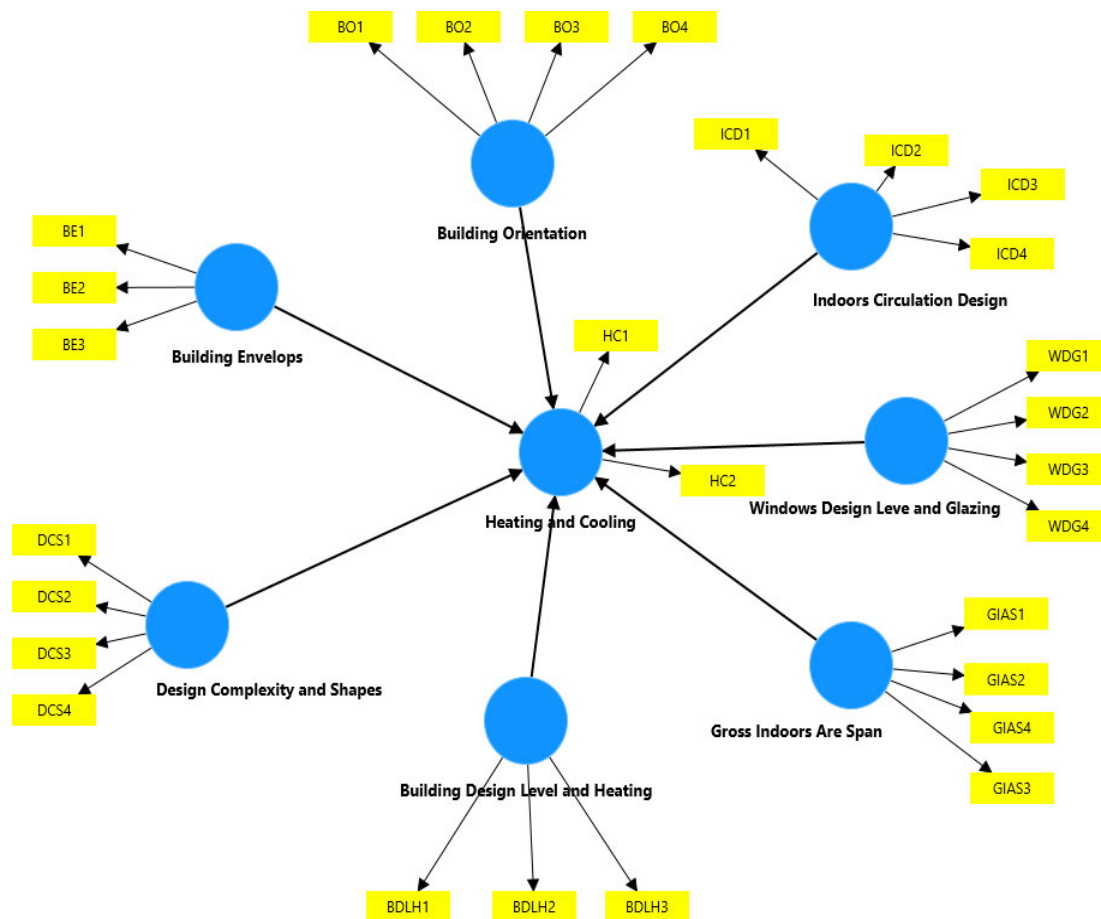


Figure 5.2 Hypothetical model1

Source: Author's Construct (2024)

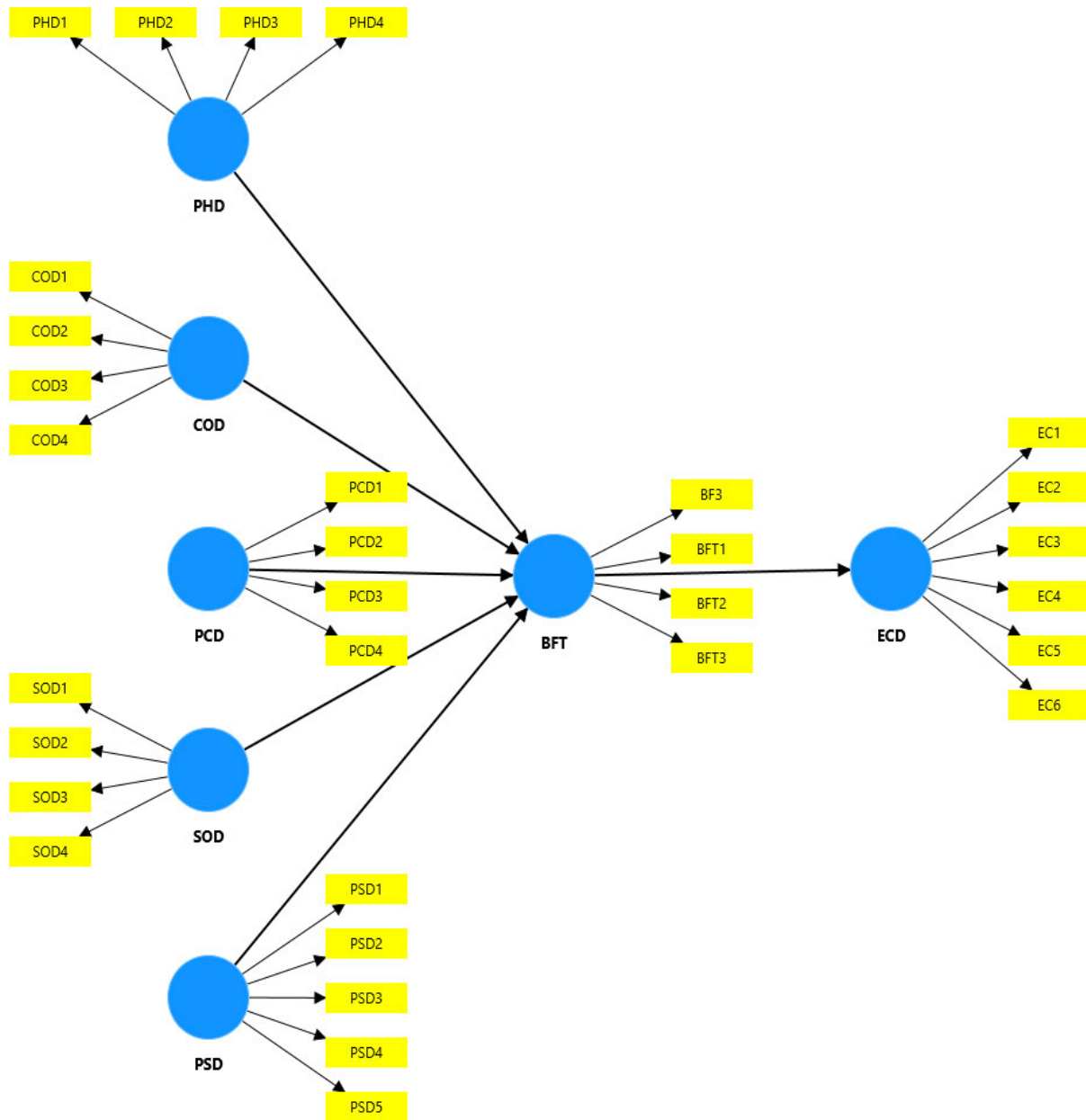


Figure 5.3Hypothetical model 2

Sources: Author's Construct (2024)

5.14.3.3 Model parameter estimation and fit

Model parameter estimation have been widely accepted to include Maximum Likelihood, Generalized Least Square, Unweighted Least Square, and Generalized Weighted Least Square. The study will adopt the Maximum likelihood approach. Model fit testing involves the use of goodness of fit index, Root mean sq. error, Comparative fit index, Tucker-Lewis index, and Normal fit index, and Incremental fit index

5.14.3.4 Measurement of model evaluation

The first step in evaluating results in PLS-SEM involves examining the measurement of model evaluation. According to Hair et al. (2016), the model evaluation describes understanding the empirical relationships between the indicators and the constructs. This assessment allows for a comparison between the theoretical framework adopted for the study and the actual data collected. For both formative and reflective constructs, the criteria for assessing the measurement model differ (Hair et al., 2019; Urbach & Ahlemann, 2010).

In this study, all constructs were reflective, necessitating an evaluation of the models reliability and validity as a first point, before proceeding to the structural model assessment. The study evaluated several aspects: indicator reliability, internal consistency reliability, convergent validity, and discriminant validity, applying standard decision rules as recommended in the literature (Hair et al., 2019; Urbach & Ahlemann, 2010). The evaluation of these measurement models is critical for ensuring that the constructs accurately reflect the underlying theoretical concepts and that the relationships among variables are valid. By confirming reliability and validity, researchers can confidently interpret the findings and draw meaningful conclusions regarding the drivers of sustainable student housing design and energy consumption behaviors. This rigorous approach to model evaluation is essential for enhancing the credibility of the research outcomes, ultimately

contributing to a deeper understanding of how various factors influence energy sustainability in student housing contexts.

5.14.3.5 Indicators and reliability test

Reliability test of a model describes the extent to which variables are consistent regarding what it intends to measure (Urbach & Ahlemann, 2010, p. 18). To check for the reliability of the indicators, reflective indicator loadings were monitored. Generally, loadings of 0.708 and above are recommended because they show that the construct or latent variable explains more than 50 percent of the variance of the indicator and thus ensures acceptable reliability of the item. (Hair et al., 2019).

5.14.3.6 Internal consistency of model

The second step in evaluating the accuracy of indicators involves using Cronbach's alpha to assess internal consistency quality. A high Cronbach's alpha value indicates that the scores of all indicators within a latent variable are consistent and meaningful (Cronbach, 1951). The minimum threshold for Cronbach's alpha is set at 0.70 (Nunnally, 1978). To address the limitations of Cronbach's alpha, composite reliability was introduced (Urbach & Ahlemann, 2010). Unlike Cronbach's alpha, composite reliability assumes that all indicators may have different loadings, making it a more accurate measure of indicator reliability (Henseler et al., 2009). Higher values indicate greater reliability, with values between 0.60 and 0.70 are considered acceptable for exploratory research. Aside, values ranging from 0.70 to 0.90 is classified as satisfactory and good reliability, while values above 0.95 are regarded as problematic, suggesting that the items may be excessive and could reduce construct reliability (Diamantopoulos et al., 2012). This rigorous approach to evaluating internal consistency ensures that the constructs being measured are reliable and valid, which is essential for drawing meaningful conclusions from the data collected in the

study. By utilizing both Cronbach's alpha and composite reliability, the research can provide a robust assessment of the measurement model before advancing to structural model evaluation. This step is crucial for ensuring that the findings related to sustainable student housing design and energy consumption behaviors are based on sound measurement practices.

5.14.3.7 Convergent validity test

Convergent validity test describes the degree to which indicators reflecting a construct converge in contrast to items measuring different constructs. (Urbach & Ahlemann, 2010). The Average Variance Extracted (AVE) forms part of the convergent validity test that measures each indicator loading on a construct based on the mean values determined. The threshold for acceptable AVE is set at 0.50 (Hair et al., 2019). This assessment is crucial because it ensures that the indicators used in the study effectively capture the underlying constructs they are intended to measure. A high AVE value indicates that a significant portion of the variance in the indicators can be attributed to the construct, confirming that they are measuring the same underlying concept. By establishing convergent validity, researchers can enhance the credibility of the findings and ensure that the models accurately reflect the relationships among variables.

5.14.3.8 Discriminant validity

The fourth step in evaluating discriminant validity involves assessing how distinct each construct is from others in the structural model. Discriminant validity describes the extent to which a construct is distinct from other constructs in the model (Hair et al., 2019). Two commonly used measures in PLS-SEM for determining discriminant validity are cross-loadings and the Fornell-Larcker criterion. The first measure, cross-loadings, involves comparing each latent variable score with all other items. If each indicator loading is higher for its respective construct than for any other construct, it can be concluded that the indicators of the latent variable are distinct and not

interchangeable (Chin, 1998). The second measure is the Fornell-Larcker criterion, which suggests that a latent variable should share more variance with its assigned indicators than with any other latent variable to achieve discriminant validity (Fornell & Larcker, 1981).

However, this criterion has faced criticism for not being suitable in situations where indicator loadings on a latent variable differ slightly (Henseler et al., 2015). As an alternative, Henseler et al. (2015) recommend using the Heterotrait-Monotrait Ratio (HTMT) of correlations as a more reliable metric for assessing discriminant validity. HTMT explains the correlations across geometric mean of the average correlations for items measuring the same construct in the model (Hair et al., 2019, p. 9). Problems with discriminant validity arise when HTMT values exceed the recommended threshold of 0.90 (Gold et al., 2001; Henseler et al., 2015). If HTMT values surpass this threshold, it indicates a lack of discriminant validity. Furthermore, bootstrapping was conducted to determine whether the HTMT value significantly differs from 1.00 or the threshold value of 0.90, as suggested by Henseler et al. (2015). This comprehensive evaluation ensures that the constructs in the study are distinct and accurately reflect the intended theoretical concepts, thereby enhancing the reliability and validity of the research findings related to sustainable student housing design and energy consumption behaviors.

5.14.3.9 Structural Model Assessment

After a positive validation of the measurement model, the next step is to test the structural model. Three essential steps were used to evaluate the structural model as suggested by (Hair et al., 2019; Urbach and Ahlemann, 2010). These steps are discussed in the subsections below:

5.14.3.10 Structural Model assessment and Multicollinearity

As part of the structural model evaluation, the first step is to examine multicollinearity. Multicollinearity occurs when there is a combination among predictors in a multiple regression

analysis (O'Brien, 2007). Multicollinearity was assessed by analyzing the variance inflation factor (VIF) for each independent construct. A minimum threshold of 5 or lower is needed to avoid issues of collinearity (Hair, Ringle, & Sarstedt, 2011). If this threshold is met, it means that the construct under consideration is almost a perfect linear combination of independent variables already in the equation (Hair et al., 2011; Hair et al., 2016; Mansfield et al., 1982).

5.14.3.11 Structural Model Assessment and Significance of Path Coefficient

After examining collinearity, it is imperative to evaluate the significance of the path coefficient between the model's latent variables (Urbach & Ahlemann, 2010). To do this, the study run a bootstrapping algorithm in SmartPLS using a large number of 5000 subsamples while using a 0.1(10%) two-tailed distribution. Bootstrapping is a "non-parametric resampling procedure that assesses the variability of a statistic by examining the variability of the sample data rather than using parametric assumptions to assess the precision of the estimates" (Streukens & Leroi Werelds, 2016). Because PLS-SEM does not show that data is normally distributed, it is necessary to run a non-parametric test using SmartPLS (Hair et al., 2016). The bootstrapping method produced t-statistics for the analysis of the direct and indirect effects of objective 4 and only direct effect for objective 1.

5.14.4 Model fit and approximation

5.14.4.1 Goodness of Fit determination

Following an evaluation of the structural model for the significance of the path coefficient, an evaluation was conducted to determine the model's goodness of fit (GOF). The assessment of this indicates whether the model is well-fitted or ill-fitted (Henseler et al., 2015). The GOF test also helps the researcher to identify misspecifications of the measurement and structural model (Dijkstra & Henseler, 2015). The R square determination coefficient (R^2) is the most widely used criteria (Hair et al., 2019). R^2 measures the model's explanatory power. It represents the combined effects of the exogenous latent variables on the endogenous latent variable (Hair, Sarstedt, Hopkins, & Kuppelwieser, 2014). R^2 varies from 0 to 1 with higher explanatory power values. As a guide, R^2 values of 0.25, 0.50 and 0.75 were used as basis to define indicators as weak, moderate and substantial respectively (Hair et al., 2011; Henseler et al., 2009). Other studies, consider considers R^2 values of 0.190 and lower as weak, values around 0.333 as average and approximate values of 0.614 as substantial (Chin, 1998).

5.14.4.2 Relative Fit Indices

The relative fit indices were deployed to examine the model fit based on the premise that all latent variables of design drivers and student behavioural indicators are uncorrelated. A set of tests which include, the Tucker-Lewis Index-TLI, Normed fit index (NFI), and Incremental Fit Index that have widely been accepted to assess the relative fit index (RFI). According Hu & Bentler (1999), model fit indices with values 0.90 are described as cut-off to predict the model. for the model to be a good fit (Singh, 2009). Hu & Bentler (1999) on the other hand reported However, cut-off to values of 0.95 as acceptable. Considering the above, the study adopted the cut-off values of 0.9 as the threshold for model decision in this study.

5.14.4.3 Non-centralized based indices

Another measure of model fitness is the non-centralised indices. Comparative Fit Index (CFI) and the Root Mean Square Error of Approximation (RMSEA) are the most recommended centrality index used in similar studies (Hu & Bentler, 1999). According to Hu and Bentler (1999), a model with a CFI and RMSEA value cut-off value of 0.90, and less than 0.08 are deemed good fit and satisfactory.

5.14.4.4 Standardized Root Mean Square Residual

The SRMSR is used to determine the differences and magnitude between the observed correlation of variables and model correlation matrix (Hair, 2019). Hu & Bentler (1998) proposed SRMSR values less than 0.08 as acceptable.

5.14.4 Relative important index (RII)

The relative important index is used to define the average means of construct based on comparative rankings. This analytical technique is a factor-determining tool that has been largely used in energy studies that focuses on energy-use intentions and residence behavioural characteristics (Dolšák, 2023; Shahzad et al., 2022; Abdou et al., 2021). The study adopted this technique to answer objective 4 question 1. Based on the literature on energy use behaviour in student housing related gadget, water closet, shower, energy-saving bulb, watching machine, artificial lighting, window opening, air-conditioning, and use of tabs in kitchen, the study grouped them into appliance management and gadget control, outdoor visual and thermal control, indoor visual and thermal control, and building services control variables (see table 5.9). Using the relative importance index formula;

$$RII = \frac{\sum w}{A * N} = \frac{1n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5}{5 * N} \text{ where } (0 \leq RII \leq 1$$

Weight was given to each respondent, ranging from: 1n as no impact, 2n as low impact, 3n as moderate impact, 4n as high impact, and 5n as very high impact. A and N on the other hand represents the highest weight and the overall number of respondents. Further, the results were ranked in ascending order of importance.

Table 5.9 students' attitude towards building energy use variables in student housing

Variables	Indicators	Construct
Appliance management and gadget control		
	Washing machine cautiously	AM1
	Leaving energy appliances on standby mode	AM2
	Using low-energy labelled electrical gadgets	AM3
	Thermostat control approach for air conditioning in the building	AM4
	Using energy-saving bulbs	AM5
Outdoor visual and thermal control		
	Closing window blinds or shade during indoor or outdoor activities	OVT1
	Controlling doors/windows airtightness	OVT2
	Using artificial lighting in a day	OVT3
Indoor visual and thermal control		
	Putting air-conditioner off when opening windows during rainy season	IVT1
	Putting air-conditioner on when windows open during the dry season	IVT2
	Turning off lights if they're not in use or needed	IVT3
Building services control		
	Usage of WC buttons during flush	BSC1
	Turning the tap off when brushing teeth or washing hands	BSC2
	Using showers instead of bathing with buckets	BSC3

Source: Author's Construct (2024)

5.16 Thematic analysis

The focus group discussions were recorded, transcribed into text, and coded based on initial codes assigned to each participant. Using Atlas Ti Software, similar responses were grouped to explain the quantitative findings related to Objectives 1, 2, and 3. This qualitative analysis allowed for a deeper understanding of the perspectives shared by participants regarding sustainable student housing design. By identifying patterns and common themes in the responses, the study could effectively link qualitative insights to the quantitative data collected through structured measures. The coding process involved categorizing responses to highlight key drivers and barriers associated with sustainable student housing. This method not only enriched the data analysis but also provided a comprehensive view of the factors influencing energy sustainability in student accommodations. The integration of qualitative findings with quantitative data enhances the overall robustness of the research, allowing for more nuanced conclusions about the requirements and challenges of sustainable student housing design in Ghana.

CHAPTER SIX

QUESTIONNAIRE SURVEY RESULTS

6.1 Biographic profile of study participants

This section provides the demographic details of the respondents, including the sex, age, educational background, and years of experience, specifically for architects. It also presents and analyzes the age, gender, and program level of student housing leaders. The demographic information of student housing managers is outlined, covering the age, gender, years of experience in student housing, and area of qualification. Lastly, the section discusses and examines the age, gender, and educational level of student housing investors.

6.1.1 Population of respondent

Table 6.1 presents the survey and focus group results of participants involved in the study. Out of 224 sampled architects, 210 participated in the survey, representing an impressive 87.5% participation rate. This high level of engagement is notable given the architects' busy schedules. Student housing managers recorded an even higher participation rate of 96.2%, which is expected due to the frequent presence in student housing facilities. Among the 65 sampled student housing investors, 56 participated in the survey, yielding a participation rate of 86.2%. Notably, student housing leaders exhibited the highest participation rate at 97.4%, indicating strong engagement that will assist in understanding student behavioral aspects and the effects on energy consumption across various campuses. The study also aimed to engage 12 energy experts for a focus group discussion; however, only 10 participated, resulting in a participation rate of 83.3%. Overall, these results indicate a high level of participation across all respondent categories, enhancing the reliability and depth of the study's findings. The next section will present the sex of participants, providing further demographic insights into the study's respondents.

Table 6.1 Survey results of participants

Participants	Sample	Survey	Percentage
Architects	224	210	87.5
Student housing manager	340	327	96.2
Student housing investors	65	56	86.2
Student housing leaders	342	333	97.4
Energy experts	12	10	83.3

Source: Field survey (2024)

6.1.2 Sex (gender) of respondent

This section presents the sex details of participants involved in the study. According to Table 6.2, male respondents comprised 80% of the architects, while female participants accounted for 20%. Similarly, among student housing managers, there were 247 males and 80 females, representing 75.5% and 24.5%, respectively. In terms of student housing leaders, male respondents were also predominant, with males constituting 61.6% and females 38.4%. Additionally, Table 6.2 indicates a higher participation of male student housing investors (76.8%) compared to the female counterparts (23.2%). These demographic insights reveal a significant gender disparity across the various roles involved in student housing management and architecture, which suggest that male respondent would have more insight on sustainable student housing design and operations in Ghana than females. Understanding these dynamics is crucial for interpreting the findings related to sustainable student housing design and energy consumption behaviors in Ghana. The next section will delve into additional demographic characteristics of the participants.

Table 6.2: Sex of respondent

	Sex	Frequency	Percent	Valid Percent	Cumulative Percent
Architects					
	Female	42	20.0	20.0	20.0
	Male	168	80.0	80.0	100.0
	Total	210	100.0	100.0	
Student housing managers					
	Female	80	24.5	24.5	24.5
	Male	247	75.5	75.5	100.0
	Total	327	100.0	100.0	
Student housing leaders					
	Female	128	38.4	38.4	38.4
	Male	205	61.6	61.6	100.0
	Total	333	100.0	100.0	
Student housing investors					
	Female	13	23.2	23.2	23.2
	Male	43	76.8	76.8	100.0
	Total	56	100.0	100.0	

(Source: field survey, 2024)

The high participation of male architects in the survey indicates a significant gender dominance within the architecture industry. This trend is further reflected in the student housing management sector, where a substantial proportion of student housing managers are also male, suggesting that men predominantly occupy leadership roles in the on-campus student housing market in Ghana. Additionally, the notable participation of male student housing investors highlights a concerning trend: limited female ownership of on-campus student housing. These findings underscore the need for further exploration into gender dynamics within the architecture and student housing sectors. Addressing this imbalance may require targeted initiatives to encourage female participation and investment in these fields, fostering a more equitable representation and potentially leading to diverse perspectives in sustainable design and energy management. This analysis aligns with broader discussions in literature regarding the influence of social norms and gender roles on professional engagement and ownership in various sectors, including architecture and real estate.

Understanding these dynamics can inform strategies aimed at promoting inclusivity and sustainability in student housing design and management.

6.1.3 Age of respondents

Table 6.3 presents the age distribution of respondents in the study. A significant proportion of architects fell within the age ranges of 36-40, 46-50, and 51-55 years. For student housing managers, approximately 35.8% were aged 41-45, while 31.8% were in the 36-40 age bracket. Among student housing investors, the study revealed that a notable percentage were aged between 46-50 (28.6%) and 51-55 (23.2%). Additionally, student housing leaders showed a younger demographic, with the highest participation rates among those aged 21-23 (25.5%) and 24-26 (48.3%). These findings highlight the diverse age ranges represented across different roles in student housing management and architecture. The predominance of younger leaders may suggest a fresh perspective on sustainable practices, while the age distribution among architects and managers reflects a balance of experience and emerging talent in the field. Understanding these demographics is crucial for interpreting the results related to sustainable student housing design and energy consumption behaviors in Ghana.

Table 6.3 Age of respondent

	Ages	Frequency	Percent	Valid Percent	Cumulative Percent
Architects					
	25-30	5	2.4	2.4	2.4
	31-35	23	11.0	11.0	13.3
	36-40	51	24.3	24.3	37.6
	41-45	37	17.6	17.6	55.2
	46-50	45	21.4	21.4	76.7
	51-55	49	23.3	23.3	100.0
	Total	210	100.0	100.0	
Student housing managers					
	25-30	1	.3	.3	.3
	31-35	21	6.4	6.4	6.7
	36-40	104	31.8	31.8	38.5
	41-45	117	35.8	35.8	74.3

	46-50	62	19.0	19.0	93.3
	51-55	22	6.7	6.7	100.0
	Total	327	100.0	100.0	
Student housing investors					
	40-45	8	14.3	14.3	14.3
	46-50	16	28.6	28.6	42.9
	51-55	13	23.2	23.2	66.1
	56-60	10	17.9	17.9	83.9
	61-65	9	16.1	16.1	100.0
	Total	56	100.0	100.0	
Student housing leaders					
	18-20	14	4.2	4.2	4.2
	21-23	85	25.5	25.5	29.7
	24-26	161	48.3	48.3	78.1
	27-29	35	10.5	10.5	88.6
	30-33	25	7.5	7.5	96.1
	34-36	13	3.9	3.9	100.0
	Total	333	100.0	100.0	

Source: Field survey (2024)

The analysis of age demographics from Table 6.3 indicates that a significant proportion of architects in the survey are older, which suggests a high level of experience in the industry. This experience can enhance the quality of information provided in the study. The age distribution among student housing managers, with notable percentages in the 41-45 and 36-40 age ranges, further indicates a solid understanding of students' energy use behaviors in student housing in Ghana. Conversely, the younger age group of student housing leaders, particularly those aged 24-26, reflects a new generation of leadership within the on-campus student housing market. This demographic may bring innovative perspectives to energy management and sustainability practices. For student housing investors, the majority being aged 46-50 (28.6%) and 51-55 (23.2%) signifies that experienced individuals dominate this sector as well, contributing valuable insights into on-campus student housing dynamics in Ghana. Overall, these age demographics highlight the blend of experience and youthful leadership across various roles in student housing, which is crucial for understanding and enhancing energy sustainability practices. The next section will

present the levels of education of participants, further enriching the demographic profile of respondents.

6.1.4 Levels of education

This section presents findings of the educational levels of respondents. As shown in table 6.4, majority of architects had bachelor's degree, representing 74.3%. On the other hand, most student housing managers had bachelor's degree similar to architects, representing 58.4%. Also, it was observed that most student housing investors completed undergraduate levels with bachelors' degrees. With respect to student housing leaders, a large proportion 213(64.4%) were level 400 students.

Table 2 Level of education of respondent

	Level	Frequency	Percent	Valid Percent	Cumulative Percent
Architects					
	Bachelors	156	74.3	74.3	74.3
	Masters	47	22.4	22.4	96.7
	PhD	7	3.3	3.3	100.0
	Total	210	100.0	100.0	
Student housing managers					
	Bachelors	191	58.4	58.4	58.4
	Diploma	90	27.5	27.5	85.9
	HND	11	3.4	3.4	89.3
	Masters	35	10.7	10.7	100.0
	Total	327	100.0	100.0	
Student housing investors					
	Bachelors	48	85.7	85.7	85.7
	Masters	8	14.3	14.3	100.0
	Total	56	100.0	100.0	
Student housing leaders					
	200	23	6.9	6.9	6.9
	300	97	29.1	29.1	36.0
	400	213	64.0	64.0	100.0
	Total	333	100.0	100.0	

Source: Field survey (2024)

The findings presented in Table 6.4 indicate that the high levels of education among architects in Ghana reflect the knowledge and expertise within the architecture industry. This educational

background positively impacts the identification of critical requirements, drivers, and barriers related to sustainable student housing design and energy sustainability in Ghana. Additionally, while a significant proportion of student housing managers hold bachelor's degrees, the presence of 10.7% with master's degrees suggests a level of experience that enhances the capabilities in managing student housing effectively. The educational qualifications of student housing investors, predominantly at the bachelor's level, also paint a favorable picture for the on-campus student housing market. Furthermore, the majority of student housing leaders being at level 400 indicates the extensive experience in student housing, which contributes to the understanding of energy use behaviors. This combination of educational attainment and practical experience among various stakeholders is crucial for fostering effective strategies aimed at improving energy sustainability in student accommodations. Overall, these insights underscore the importance of education in shaping the competencies and perspectives of professionals involved in sustainable student housing design and management. The next section will delve into other relevant demographic characteristics of participants.

6.1.5 Summary of descriptive

The descriptive results show that the majority of respondents across various groups and study areas were male. In terms of age, architects predominantly fell within the 36-40, 46-50, and 51-55 age ranges. Student housing managers were mostly aged 41-45 and 36-40, while student housing investors were primarily in the 46-50 and 51-55 age brackets. Student housing leaders showed a younger demographic, with the highest participation among those aged 21-23 and 24-26. Regarding educational attainment, a significant proportion of respondents had bachelor's degrees: architects (74.3%), student housing managers (58.4%), and student housing investors (85.7%). Most student housing leaders were at the level 400 stage of the education. These demographic

insights highlight the gender dynamics, age distribution, and educational backgrounds of participants, providing context for understanding the perspectives on sustainable student housing design and energy consumption behaviors in Ghana. The next steps in the analysis will explore how these factors influence the findings related to energy sustainability in student accommodations.

6.2 Critical factors of consideration of building requirements in student housing

Table 6.5 presents the critical factors of student housing design requirements for indoor environmental energy sustainability in Ghana. The study assessed various design requirements, including building envelope, building orientation, indoor circulation space, building design and geometry, design complexity and shape, building height and storey levels, window glazing and efficiency, and gross indoor area span. According to the results, out of the seven drivers evaluated, only four were deemed critical for student housing design: indoor circulation space, gross indoor span area, window design and glazing efficiency, and design complexity and shape. These factors recorded mean values above the average, indicating that architects prioritize these requirements when designing student housing in Ghana. Conversely, the findings also revealed limited consideration for other sustainable building design requirements such as building envelope, building height and storey levels, and building orientation. This suggests that while these elements are important for overall design, they may not be viewed as critical to achieving indoor environmental energy sustainability in student housing. This analysis underscores the significance of specific design requirements in shaping sustainable student housing practices. By focusing on the critical factors, architects can enhance energy efficiency and sustainability in student accommodations across Ghana.

Table 6.5 factors that defines sustainable student housing in Ghana

	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
BE	1	5	2	0.619	0.746	0.169	2.111	0.337
BDLH	1	5	2.22	1.622	0.794	0.169	-1.09	0.337
BO	1	5	2.4	0.959	1.166	0.169	1.242	0.337
DSC	1	5	3.07	0.806	0.26	0.169	1.671	0.337
GIA	1	5	3.28	1.023	-0.612	0.169	-0.624	0.337
WDGI	1	5	3.62	0.947	-1.245	0.169	1.025	0.337
ICD	1	5	4.43	0.992	-2.022	0.169	3.785	0.337
Valid N (listwise)								
Average mean score		3.002857						

(source: Field survey, 2024)

Note: (Denote: BE=building envelop, BDLH=Building Design Level and Height, BO=Building Orientation, DSC=Design Complexity and Shape, GIA=Gross Indoor Area, WDGI=Window Design Glazing, and ICD=Indoor Circulation Design)

6.2.1 Key indicators influencing the drivers of student housing design requirements in Ghana

This section presents the results of key indicators influencing student housing design requirements in Ghana. According to Table 6.6, architects place significant importance on circulation space within buildings, as well as access to communal areas and exits when designing student housing. They believe that a logical flow within the rooms can positively influence indoor environmental energy sustainability in Ghana. The study also found that efficient circulation routes and convenience in rooms are critical, with mean scores indicating the importance (mean score of 3.43 compared to an average mean score of 3.34).

Additionally, the study identified ventilation and acoustic performance, sun shading geometry, and the shape of window glazing as critical indicators for window design and glazing requirements (see Table 6.6). However, there was low consideration for the efficiency of window glazing in student housing design, suggesting that achieving efficient indoor environmental energy sustainability may be challenging. Table 6.6 also reported three key indicators of gross indoor area span requirements in student housing that exceeded the average mean score: indoor floor dimension, indoor space flexibility, and size of usable areas. This implies a strong expectation for sustainable indoor environmental energy in student housing. However, the proportion of indoor circulation space was not adequately considered in the design process. Furthermore, out of four indicators related to building environmental performance, only two were deemed relevant: building environmental performance and building compatibility with the external environment (see Table 6.6). Conversely, architects showed limited consideration for building shape complexities and design efficiency, indicating that more complex designs could negatively impact indoor energy sustainability. The study also found that building orientation concerning wind and sun exposure is a critical indicator in designing student housing in Ghana. Despite this, architects noted limited attention to factors such as privacy and shielding from external noise related to building orientation (see Table 6.6), which poses a threat to sustainable indoor energy management. Finally, architects largely considered building mass form as a critical requirement for the building envelope in student housing design, with mean values (3.58) exceeding the average mean score (3.34). Interestingly, there was a low level of consideration for glazing requirements and the nature of façade materials within building envelope requirements. These findings highlight the need for a more holistic approach to student housing design that prioritizes both functionality and sustainability to improve energy efficiency in Ghana's educational environments.

Table 36.6 key drivers affecting student housing requirements of sustainable student housing in Ghana

	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
ICD3	1	5	4.46	1.152	-1.843	0.169	1.727	0.337
ICD1	1	5	4.33	1.186	-1.428	0.169	0.310	0.337
ICD2	1	4	3.50	0.897	-1.495	0.169	0.754	0.337
ICD4	1	5	3.43	0.977	-1.267	0.169	0.334	0.337
WDG1	1	5	3.62	1.035	-1.183	0.169	0.837	0.337
WDG3	1	5	4.24	1.376	-1.516	0.169	0.671	0.337
WDG4	1	5	4.32	1.324	-1.682	0.169	1.193	0.337
WDG2	1	5	2.72	0.858	-0.681	0.169	0.573	0.337
GIA2	1	5	4.33	1.162	-1.672	0.169	1.758	0.337
GIA3	1	5	3.59	0.881	-1.989	0.169	3.126	0.337
GIA1	1	5	3.48	1.047	-1.353	0.169	0.929	0.337
GIA4	1	5	2.31	0.921	1.483	0.169	1.945	0.337
DCS3	1	5	3.51	0.902	-1.463	0.169	1.277	0.337
DCS4	1	5	3.53	0.897	-1.407	0.169	1.652	0.337
DCS1	1	5	3.23	0.882	-0.033	0.169	0.760	0.337
DCS2	1	5	2.17	0.767	1.594	0.169	3.479	0.337
BO3	1	5	4.46	1.118	-2.129	0.169	3.271	0.337
BO2	1	5	3.33	1.281	-0.981	0.169	-0.597	0.337
BO4	1	5	2.79	0.746	-0.766	0.169	1.818	0.337
BO1	1	5	2.66	1.157	0.005	0.169	-0.317	0.337
BDLH3	1	5	3.61	1.003	-1.395	0.169	1.408	0.337
BDLH2	1	5	3.22	0.824	0.092	0.169	0.893	0.337
BDLH1	1	5	2.26	0.800	1.675	0.169	4.031	0.337
BE2	1	5	3.58	1.020	-1.187	0.169	0.576	0.337
BE1	1	5	2.22	0.928	1.765	0.169	3.482	0.337
BE3	1	4	1.82	0.523	0.630	0.169	4.504	0.337
Valid N (listwise)								
Average mean score				3.34				

(source: Field survey, 2024)

Note: (Denote: BE=building envelop, BDLH=Building Design Level and Height, BO=Building Orientation, DSC=Design Complexity and Shape, GIA=Gross Indoor Area, WDG=Window Design Glazing, and ICD=Indoor Circulation Design).

6.3 Measurement Model Evaluation

This section evaluated the model to ascertain the relationship between the indicators and constructs of the model. This is to understand whether the compliance with student housing requirements have direct relationship on heating and cooling systems in student housing. The evaluation criteria involved the reliability of the indicator convergent validity and discriminatory validity based on structural equation model rules (Hair et al., 2019)

6.4 Internal reliability consistency and convergent validity

Table 6.7 presents the construct reliability results of the model. Using Cronbach's alpha to test internal consistency quality, all latent variables or constructs achieved an alpha value exceeding 0.70, as supported by Hair et al. (2019). Furthermore, the composite reliability values ranged from 0.725 to 0.943, indicating a level of reliability that is classified as "satisfactory" to "good" (Diamantopoulos et al., 2012). Additionally, Table 6.7 reported composite reliability (ρ_A) values higher than the recommended threshold, as indicated by Dijkstra and Henseler (2015). The convergent validity assessment revealed Average Variance Extracted (AVE) values surpassing the 0.50 threshold, aligning with Hair et al. (2019). This implies that each latent factor contributes about 50% of the capriciousness of its items, demonstrating sufficient convergent validity. These findings collectively affirm the consistency and legitimacy of the constructs used in the study, indicating a solid underpinning for further analysis regarding sustainable student housing design and energy sustainability in Ghana.

Table 6.7 Internal reliability consistency and convergent validity

Constructs	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Building Design Level and Heating	0.929	0.934	0.955	0.875
Building Envelops	0.843	0.857	0.906	0.762
Building Orientation	0.815	0.832	0.874	0.635
Design Complexity and Shapes	0.920	0.920	0.943	0.806
Gross Indoors Area Span	0.929	0.931	0.950	0.825
Heating and Cooling	0.725	0.725	0.879	0.784
Indoors Circulation Design	0.800	0.836	0.865	0.617
Windows Design Level and Glazing	0.888	0.892	0.923	0.749

Source: Author's Construct (2024)

6.4.1 Discriminant Validity

The section evaluates the extent to which constructs are empirically distinct from one another in the structural model. Using PLS-SEM, the results indicated that cross-loadings were derived from the assessment of scores of each latent variable compared with all other items. The findings show that each latent variable loads the highest with its assigned indicators (see Table 6.8). The Fornell and Larcker criterion further demonstrated that each latent variable shares more variance than any other latent variable. This is evidenced by the bold numbers in Table 6.9, suggesting that the Average Variance Extracted (AVE) for each latent variable surpasses the highest square correlation among the latent variables. Moreover, the study assessed whether latent variable loadings differ slightly—specifically in cases where loadings range from 0.65 to 0.85—by utilizing

the Heterotrait-Monotrait Ratio (HTMT) of correlations. As shown in Table 6.10, all HTMT values did not exceed the threshold of 0.90, confirming that discriminant validity has been achieved. These results affirm that the constructs used in the model are distinct and valid, providing a solid foundation for further analysis related to sustainable student housing design and energy sustainability in Ghana. The findings highlight the relevance of ensuring both convergent and discriminant validity in structural equation modeling to enhance the reliability of research outcomes.

Table 46.8 Discriminant validity test

Measurement Items	Building Design Level & Heating	Building Envelops	Building Orientation	Design Complexity & Shapes	Gross Indoors Area Span	Heating & Cooling	Indoors Circulation Design	Windows Design Level & Glazing
BDLH1	0.928	0.720	0.597	0.834	0.927	0.777	0.650	0.786
BDLH2	0.932	0.685	0.590	0.819	0.907	0.784	0.610	0.786
BDLH3	0.946	0.690	0.577	0.800	0.854	0.889	0.609	0.773
BE1	0.598	0.908	0.672	0.630	0.627	0.738	0.866	0.730
BE2	0.601	0.900	0.722	0.644	0.613	0.882	0.811	0.815
BE3	0.773	0.808	0.580	0.809	0.794	0.707	0.649	0.866
BO1	0.478	0.514	0.826	0.433	0.458	0.526	0.645	0.491
BO2	0.381	0.484	0.823	0.373	0.383	0.487	0.728	0.442
BO3	0.352	0.490	0.791	0.398	0.376	0.447	0.703	0.465
BO4	0.669	0.798	0.774	0.680	0.679	0.754	0.833	0.759
DCS1	0.757	0.704	0.532	0.896	0.798	0.724	0.582	0.881
DCS2	0.776	0.738	0.613	0.901	0.807	0.755	0.662	0.898
DCS3	0.789	0.711	0.542	0.903	0.889	0.747	0.617	0.798
DCS4	0.813	0.677	0.569	0.891	0.909	0.705	0.617	0.771
GIAS1	0.789	0.711	0.542	0.903	0.889	0.747	0.617	0.798
GIAS2	0.813	0.677	0.569	0.891	0.909	0.705	0.617	0.771
GIAS3	0.928	0.720	0.597	0.834	0.927	0.777	0.650	0.786
GIAS4	0.932	0.685	0.590	0.819	0.967	0.784	0.610	0.786
HC1	0.946	0.690	0.577	0.800	0.854	0.889	0.609	0.773
HC2	0.601	0.900	0.722	0.644	0.613	0.882	0.811	0.815
ICD1	0.381	0.484	0.823	0.373	0.383	0.487	0.728	0.442
ICD2	0.352	0.490	0.791	0.398	0.376	0.447	0.803	0.465
ICD3	0.669	0.798	0.744	0.680	0.679	0.754	0.833	0.759
ICD4	0.598	0.908	0.672	0.630	0.627	0.738	0.966	0.730

WDG1	0.601	0.800	0.722	0.644	0.613	0.882	0.811	0.895
WDG2	0.773	0.808	0.580	0.809	0.794	0.707	0.649	0.866
WDG3	0.757	0.704	0.532	0.896	0.798	0.724	0.582	0.898
WDG4	0.776	0.738	0.613	0.901	0.807	0.755	0.662	0.998

Source: Field survey (2024)

Table 6.9 Discriminant Validity (Fornell-Larcker Criterion)

Constructs	Building Design Level & Heating	Building Envelops	Building Orientation	Design Complexity and Shapes	Gross Indoors Area Span	Heating and Cooling	Indoors Circulation Design	Windows Design Level and Glazing
Building Design Level & Heating	0.935							
Building Envelops	0.745	0.873						
Building Orientation	0.628	0.758	0.797					
Design Complexity and Shapes	0.873	0.789	0.629	0.898				
Gross Indoors Area Span	0.955	0.769	0.633	0.947	0.995			
Heating and Cooling	0.876	0.895	0.733	0.816	0.831	0.985		
Indoors Circulation Design	0.665	0.891	0.935	0.690	0.687	0.800	0.986	
Windows Design Level and Glazing	0.835	0.919	0.716	0.933	0.865	0.896	0.792	0.965

(source: field survey, 2024)

Construct	Building Design Level and Heating	Building Envelops	Building Orientation	Design Complexity & Shapes	Gross Indoors Area Span	Heating and Cooling	Indoors Circulation Design	Windows Design Level and Glazing
Building Design Level & Heating								
Building Envelops	0.852							
Building Orientation	0.675	0.854						
Design Complexity & Shapes	0.846	0.803	0.678					

Gross Indoors Area Span	0.792	0.878	0.679	0.827				
Heating and Cooling	0.612	0.839	0.800	0.898	0.808			
Indoors Circulation Design	0.735	0.727	0.771	0.767	0.757	0.810		
Windows Design Level & Glazing	0.825	0.855	0.780	0.638	0.858	0.834	0.886	

Table 56.10 Discriminant Validity-Heterotrait-Monotrait Ratio (HTMT)

Source: Field survey (2024)

6.5 Structural Model Assessment

This section assesses the structural model results using five essential steps as suggested by Hair et al. (2019): identification of multicollinearity issues, Goodness-of-Fit (GOF), total effects, effect size, and direct effects. The first step involves checking for multicollinearity among the constructs. High multicollinearity can distort the results of the model, making it difficult to assess the individual contributions of each construct. Variance Inflation Factor (VIF) values were calculated, with values exceeding 5 indicating potential multicollinearity issues. The Goodness-of-Fit index provides an overall measure of how well the model fits the data. A GOF value above 0.36 indicates a good fit, signifying adequate relationships among constructs. Effect size measures the impact of an independent variable on a dependent variable within the model. Cohen's f^2 values were calculated to assess the effect size, with values 0.351, 0.151, and 0.021 representing large, medium, and small impact, respectively.

Total effects represent the cumulative impact of all paths leading to a specific dependent variable within the model. This assessment helps in understanding how various constructs interact and influence outcomes related to energy sustainability in student housing. The direct effects indicate the immediate impact of one construct on another without mediation from other variables. These

relationships were analyzed to identify key drivers influencing sustainable student housing design. By following these steps, the structural model results provide valuable insights into the relationships among constructs and the implications for energy sustainability in Ghana's student housing context. The findings contribute to a deeper understanding of how various factors interact to shape energy consumption behaviors and inform future design practices in this sector.

6.6 Assessing Structural Model for Multicollinearity Issues

Table 6.11 reports the Variance Inflation Factor (VIF) for each independent construct to assess multicollinearity. According to Hair et al. (2011), a VIF threshold of 5 or lower is necessary to avoid collinearity issues. From the results presented in Table 6.11, all VIF values are below 5, indicating that there are no multicollinearity concerns regarding the student housing design requirements related to heating and cooling in this study. This finding suggests that the constructs used in the model are sufficiently distinct from one another, allowing for a clearer interpretation of the individual contributions to the overall model. By ensuring that multicollinearity is not an issue, the study enhances the reliability of its findings concerning sustainable student housing design in Ghana.

Table 6.11 Multicollinearity Statistics (VIF)

Constructs	Building Design Level & Heating	Building Envelops	Building Orientation	Design Complexity & Shapes	Gross Indoors Area Span	Heating and Cooling	Indoors Circulation Design	Windows Design Level & Glazing
Building Design Level & Heating						4.847		
Building Envelops						4.460		
Building Orientation						4.618		
Design Complexity & Shapes						2.751		
Gross Indoors Are Span						3.116		
Heating & Cooling								

Indoors Circulation Design						4.755		
Windows Design Leve & Glazing						3.717		

Source: Field survey (2024)

6.6 Goodness of Fit

The Goodness-of-Fit (GOF) assessment indicates whether the model is well-fitted. Using the R^2 determination coefficient, the study reported a value of 0.931, which is considered substantial. This high R^2 value demonstrates the model's strong explanatory power regarding the influence of student housing design requirements on heating and cooling systems in student housing in Ghana. A value of 0.931 suggests that a significant portion of the variance in heating and cooling outcomes can be explained by the identified design requirements, reinforcing the importance of these factors in achieving energy sustainability within student housing contexts (see Table 6.12). This robust explanatory capacity indicates that the model effectively captures the relationships among constructs, providing valuable insights for architects and policymakers involved in sustainable student housing design.

Table 6.12 Goodness-of-fit test

Dependent Construct	R-square	R-square adjusted
Heating and Cooling	0.931	0.929

Source: Field survey (2024)

6.7 Relative fit index and non-centralized based indices results

The study further assessed the relative fit index and non-centralized based indices for Model 1 and Model 2. As shown in Table 6.13, the SEM analysis revealed that the relative fit indices for TLI, IFI, and NFI recorded satisfactory values. Additionally, the non-centralized indices, including the Comparative Fit Index (CFI) and the Root Mean Square Error of Approximation (RMSEA), were found to be good (see Table 6.13). These results imply that the model is robust in predicting the

contributions of student housing design requirements on energy consumption. The satisfactory model fit indices indicate that the model effectively captures the relationships among constructs, providing a reliable framework for understanding how design elements influence energy efficiency in student housing in Ghana. This strong predictive capability emphasizes the significance of considering these design requirements in efforts to enhance energy sustainability within the sector.

Table 66.13 Robustness of model 1

Model fit	Threshold	Estimated
Tucker-Lewis Index-TLI	> 0.80 (Bentler & Bonnet, 1980)	0.824
Comparative Fit Index	0.95 Hu and Bentler (1999).	0.903
Incremental Fit Index-IFI	> 0.90 (Bentler & Bonnet, 1980)	0.914
Root Mean Square Estimator of Approximation-RMSEA	0.08 and 0.10 (mediocre model fit), < 0.08 (MacCallum et al., 1996) < 0.07, as good (Steiger, 2007)	0.053
Normed fit index-NFI	> 0.90 (Bentler & Bonnet, 1980)	0.903

Source: Field survey (2024)

6.8 Assessing the Effect Size of model 1

This section presents the effect size of model 1, emphasizing on the contributions of the dependent construct on the independent constructs. Using SmartPLS, the f^2 values indicated that several design factors have fluctuating levels of effect on energy consumption in student housing. Specifically, building orientation, design complexity and shapes, indoor circulation design, and window design level and glazing reported small effect sizes, with values ranging between 0.020 and 0.150 (see Table 6.14). In contrast, the gross indoor area span recorded a medium effect size, falling between 0.150 and 0.350. Notably, both building design level and heating systems along with building envelopes exhibited high effect sizes, with values exceeding 0.

350. These results imply that the exogenous latent variables significantly influence the dependent construct—specifically, heating and cooling systems—which aligns with findings from Gefen et al. (2000). This highlights the importance of considering these design requirements to enhance energy efficiency in student housing, thereby contributing to sustainable practices in this sector.

Table 6.14 F-Square test results of model 1

Construct	Building Design Level and Heating	Building Envelops	Building Orientation	Design Complexity and Shapes	Gross Indoors Area Span	Heating and Cooling	Indoors Circulation Design	Windows Design Level and Glazing
Building Design Level & Heating						0.836		
Building Envelops						0.355		
Building Orientation						0.102		
Design Complexity & Shapes						0.118		
Gross Indoors Are Span						0.290		
Heating & Cooling								
Indoors Circulation Design						0.082		
Windows Design Level & Glazing						0.067		

Source: Field survey (2024)

6.9 Hypothesis testing the relationship of student housing design requirements on heating and cooling in Ghana

This section presents results on the significant relationship between the effects of student housing requirements on heating and cooling in Ghana. Figure 6.1 shows that there is positive significant relationship between the latent and observed variables (thus, indicators are less than 0.05).

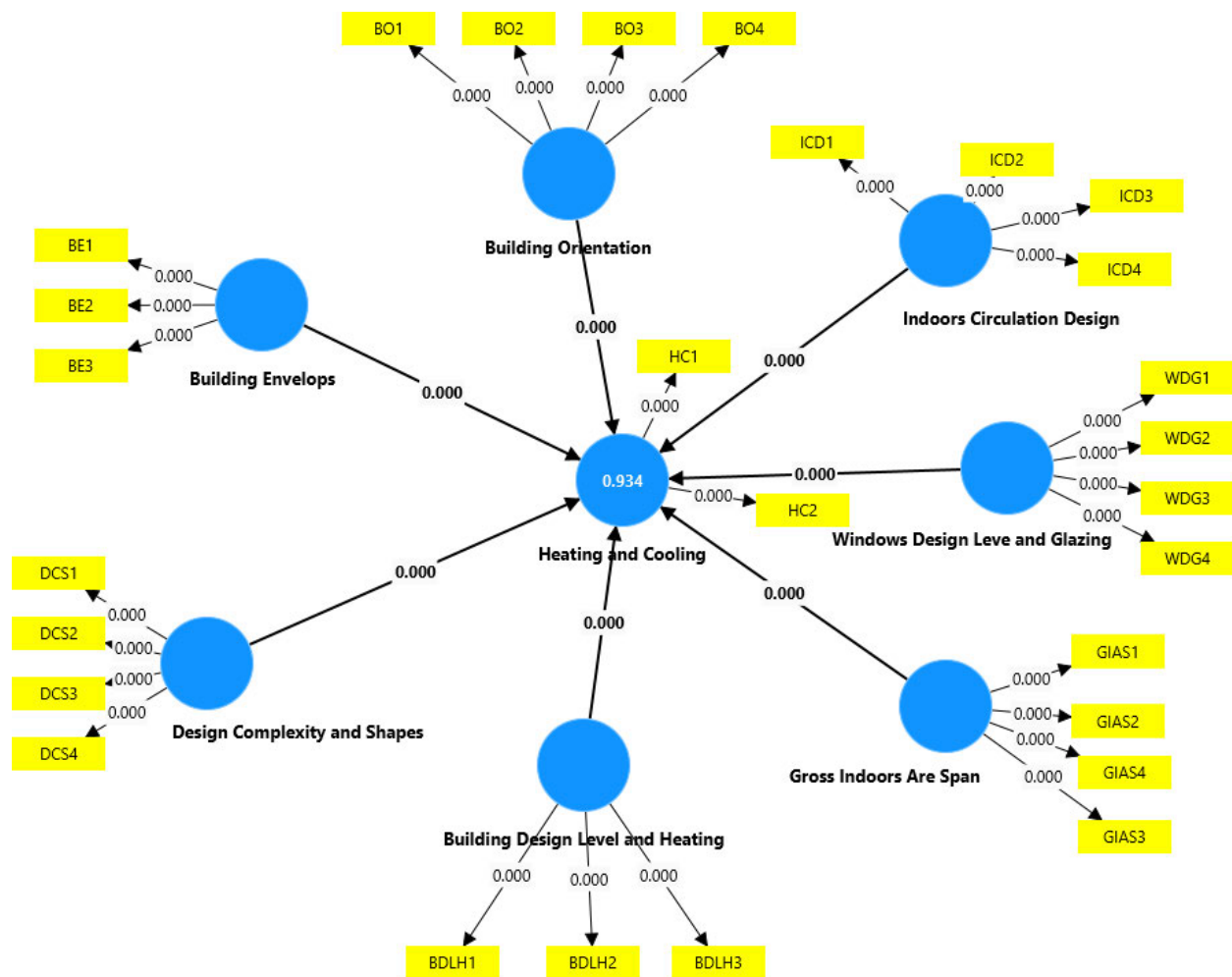


Figure 6.1 Testing of significance of hypothesis

Source: Author's Construct (2024)

6.10 Direct effects of student housing requirements on heating and cooling in Ghana

This section explains the contributory effects of student housing design requirements, drivers, and indicators on heating and cooling systems in student housing. To assess the indicator effects, reflective indicator loadings were monitored. It is recommended that indicator loadings be 0.708 or higher, as this indicates that the construct or latent variable explains more than 50% of the variance of the indicator, ensuring acceptable reliability (Hair et al., 2019). Initially, some indicators did not meet the minimum threshold; specifically, BDLH4 had a loading of 0.697 and was subsequently deleted. After removing BDLH4, the model was re-run using the PLS algorithm,

resulting in all remaining indicators loading significantly on the corresponding latent variables (see Figure 6.2). This adjustment ensured that all indicators satisfied the minimum requirement, confirming the effectiveness as measurements of the latent variables. The results indicated that student housing design requirements contribute approximately 0.932 variance to heating and cooling systems, which translates to about 93.2% influence on these systems in Ghana. This strong contribution underscores the importance of specific design elements in enhancing energy efficiency and sustainability within student housing contexts. Overall, these findings highlight how critical it is to focus on well-defined design requirements to optimize heating and cooling performance in student accommodations, thereby supporting broader goals of energy sustainability in Ghana.

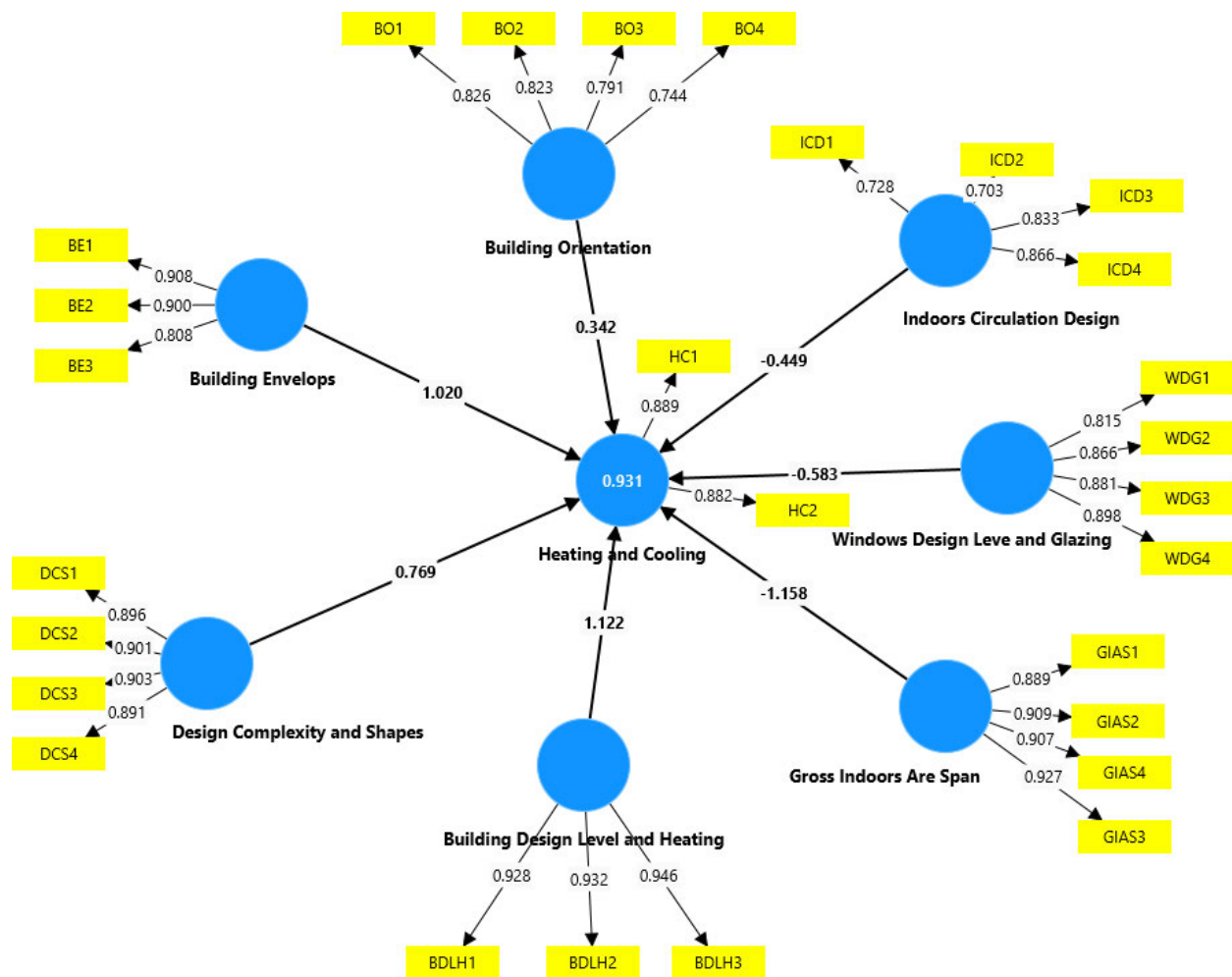


Figure 6.2 effects of student housing design requirements on heating and cooling

Source: Author's Construct (2024)

According to Figure 6.2, all observed indicators of building orientation were above the threshold of 0.708, with BO1 recording an effect of 82.6% on heating and cooling, while BO4 had the lowest effect at 74.4%. Similarly, all observed indicators of building envelope also recorded very high values, with BE1 reaching 90.08%, closely followed by BE2 at 90.0%. In terms of indoor circulation design, indicators ICD3, ICD4, and ICD1 reported values above the minimum threshold; however, ICD2 fell below this threshold. Other constructs also showed strong performance: BDHL3 recorded the highest effect at 94.6%, followed by GIAS2 at 90.9%, WDG4 at 89.8%, and DCS3 at 90.3%. These results highlight the significant contributions these design

requirements make to heating and cooling in student housing. Table 6.15 presents the overall path coefficients of the model. Using a bootstrapping approach to assess normal distribution, t-statistics were employed as the unit of analysis. The test statistics indicated that all seven hypotheses were supported, with critical t-values of 1.65 and above (see Table 6.15). Notably, the path coefficient for building design level and heating recorded the strongest positive direct effect at 1.122 on heating and cooling systems. Furthermore, an increase in compliance with building envelope requirements was found to enhance heating and cooling by 100.2% in student housing in Ghana. Building design complexity and shape also exhibited a significant positive impact on heating and cooling, recording an effect of 76.9%. However, the study identified negative effects associated with gross indoor area span, indoor circulation design, and window design level and glazing. This finding raises concerns about energy consumption in student housing in Ghana, indicating potential threats to achieving energy efficiency. Overall, these insights underscore the importance of focusing on effective design requirements to optimize heating and cooling performance in student accommodations, thereby contributing to broader energy sustainability goals in the region.

Table 6.15 Direct Relationship for Hypothesis Testing

Hypothesis	Relationship	Path Coefficient	T Values	Interpretation
H1	Building Design Level and Heating -> Heating and Cooling	1.122	15.314	Supported
H2	Building Envelops -> Heating and Cooling	1.020	6.692	Supported
H3	Building Orientation -> Heating and Cooling	0.342	4.722	Supported
H4	Design Complexity and Shapes -> Heating and Cooling	0.769	4.885	Supported
H5	Gross Indoors Area Span -> Heating and Cooling	-1.158	8.302	Supported
H6	Indoors Circulation Design -> Heating and Cooling	-0.449	3.864	Supported
H7	Windows Design Level and Glazing -> Heating and Cooling	-0.583	3.612	Supported

Source: Author's Construct (2024)

6.11 Summary of critical drivers of sustainable student housing design

To achieve Objective 1, the study assessed the critical drivers of sustainable student housing design and the effects on heating and cooling in Ghana. The results demonstrated a high explanatory power for several factors, including building envelope, building orientation, design levels and height, window glazing and design, indoor circulation design, and gross indoor span. However, it was noted that indoor circulation design, gross indoor span, and window design and glazing exhibited lower compliance, resulting in negative and significant effects on heating and cooling in student housing. The model evaluation and fit tests yielded positive results, exceeding the required thresholds for model testing. This indicates that the constructs used in the study are reliable and valid, effectively capturing the relationships among the various design requirements and the influence on energy consumption. Overall, these findings highlight the importance of focusing on specific design elements to enhance energy efficiency in student housing, ultimately contributing to sustainable practices in Ghana.

6.12 Drivers of Sustainable Student Housing Design in Ghana

This section presents results on the key drivers influencing sustainable student housing designs in Ghana, structured into five sections to achieve Objective Two of the study. This section provides an overview of the critical drivers identified for sustainable student housing design. Initial findings indicate economic, social, technological, environmental, and policy-related factors as significant influences. Previous studies have highlighted that driver such as affordability, climate change considerations, aesthetics, and energy consumption reduction play crucial roles in shaping sustainable design practices (Munaro et al., 2020; Chan & Anabre, 2019). In this section, factor analysis was conducted to identify and validate the underlying relationships among the various

drivers of sustainable student housing design. The analysis revealed that knowledge drivers, financial considerations, and health and comfort factors significantly contribute to the adaptation of sustainable practices. For instance, studies have shown that financial drivers like life cycle costs and energy savings are pivotal in decision-making for sustainable construction (Oke et al., 2024).

The third section elaborates on specific indicators that drive the adaptation of sustainable student housing design in Ghana. Key indicators include building orientation, indoor circulation design, window glazing efficiency, and building envelope characteristics. The findings suggest that while some indicators show strong positive effects on heating and cooling systems, others—such as gross indoor area span—exhibit less compliance and may negatively impact energy efficiency. The results emphasize the need for targeted policies and incentives to enhance compliance with sustainable design requirements. Government policies can play a vital role in promoting energy-efficient practices in student housing by addressing economic barriers and fostering community awareness.

The final section concludes by summarizing the importance of understanding these drivers and indicators in fostering sustainable student housing designs in Ghana. By identifying critical factors influencing design decisions, stakeholders can develop policies to improve energy efficiency and sustainability in student accommodations.

6.12.1 Descriptive statistics

According to the survey results presented in Table 4, student housing investors identified several common drivers influencing the choice for sustainable student housing in Ghana. The average responses indicate that financial drivers (Mean = 4.306998) and health drivers (Mean = 4.38149) recorded high mean values, reflecting the importance in decision-making processes. The second cohort of responses, which also showed high averages, includes building design drivers, all-

inclusive drivers, and knowledge drivers. These factors are essential in shaping sustainable practices within student housing.

In contrast, the third cohort of drivers demonstrated moderate responses, comprising economic drivers (Mean=2.277652), institutional drivers (Mean= 2.288939), and market demand drivers (Mean = 2.419865) (see Table 6.16). These lower mean values suggest that while they are recognized, they may not be as influential as the previously mentioned drivers. Lastly, environmental drivers did not show any relevant contributions to the drivers of sustainable student housing design, indicating that these factors may not be prioritized by investors in this context.

Table 6.16 descriptives of drivers of sustainable student housing design

Variable	Mean	Std. Dev.	Min	Max	Interpretation
ED	2.277652	0.833203	1	5	Moderate
FD	4.306998	1.220348	1	5	Very High
ID	2.288939	0.83343	1	5	Moderate
BD	3.638826	0.767278	1	5	High
HD	4.38149	1.007358	1	5	Very High
AD	3.146727	0.748245	1	5	High
MD	2.419865	0.807075	1	5	Moderate
KD	3.036117	0.739056	1	5	High
END	1.654628	1.065882	1	5	Low

Source: Field survey (2024)

6.12.2 Test of data sphericity

The study examined the internal reliability of drivers influencing the adaptation of sustainable student housing in Ghana. The Kaiser normalization and Bartlett's test of sphericity showed suitable values (0.827) above the threshold of 0.6 (see Table 6.17). Further, the test of sphericity

showed significant results which shows high correlation between the drivers influencing the adaptation to sustainable student housing in Ghana.

Table 6.17 data sphericity test for objective 2

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.827
Bartlett's Test of Sphericity	Approx. Chi-Square	345.588
	df	36
	Sig.	.000
Determinant		7.4E-02

Source: Field survey (2024)

6.12.3 Summary of test of Eigenvalues values defining factors

Table 6.18 presents the test of eigenvalues, which explains the strength of the factor loadings related to the drivers of sustainable student housing design in Ghana. The results indicate that all drivers recorded initial eigenvalues of 1.0, demonstrating strong communality among them. However, specific drivers such as financial drivers, building design drivers, market demand drivers, and environmental design drivers exhibited high extraction values, suggesting the significant influence on sustainable student housing design. Conversely, institutional drivers and economic drivers did not show high extraction values, indicating a lesser impact in this context. The high extraction results for the key drivers are likely to predict an increase in the influence on sustainable student housing design. This suggests that focusing on these critical drivers can enhance the effectiveness of design practices aimed at improving energy efficiency and sustainability in student housing across Ghana.

Table 6.18 test of Eigenvalues values defining factors

Communalities			
Construct	Initial	Extraction	Interpretation
ED	1.000	0.441	Average
FD	1.000	0.811	Excellent
ID	1.000	0.497	Average
BD	1.000	0.731	Very good
HD	1.000	0.597	Moderate
AD	1.000	0.695	Good
MD	1.000	0.784	Very good
KD	1.000	0.695	Good
END	1.000	0.741	Very good
Extraction Method: Principal Component Analysis.			

Source: Field survey (2024)

6.12.4 Total variance explained on drivers of sustainable student housing design

The study examined nine key drivers that influence the adaptation of student housing design in Ghana. Through factor analysis, it was determined that five out of these nine drivers exhibited the highest significance, with eigenvalues of at least 1, which is further illustrated in the scree plot (see Figure 6.3). These factors accounted for the majority of the variance in student housing design adaptation.

The first factor demonstrated a substantial cumulative variance of 14.869%, indicating its critical importance in influencing the adoption of sustainable design practices. The second, third, fourth, and fifth factors recorded cumulative extracted sums of squared loadings of 28.9587%, 42.834%, 55.311%, and 66.588%, respectively. These cumulative percentages highlight the collective contribution of these factors in explaining the variance in sustainable housing design adaptation in Ghana (see Table 6.19). The findings indicate a robust impact of these drivers on shaping

sustainable student housing designs, with the factors collectively accounting for a significant portion of the overall variance. This suggests that these elements are key determinants in influencing the adoption and implementation of sustainable practices in student housing.

Table 6.19 Total variance explained on drivers of sustainable student housing design

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.338	14.869	14.869	1.338	14.869	14.869	1.271	14.123	14.123
2	1.268	14.088	28.957	1.268	14.088	28.957	1.228	13.642	27.764
3	1.249	13.877	42.834	1.249	13.877	42.834	1.197	13.302	41.066
4	1.123	12.477	55.311	1.123	12.477	55.311	1.158	12.862	53.929
5	1.015	11.277	66.588	1.015	11.277	66.588	1.139	12.659	66.588
6	.922	10.241	76.828						
7	.846	9.395	86.224						
8	.677	7.518	93.742						
9	.563	6.258	100.000						

Extraction Method: Principal Component Analysis.

Source: Field survey (2024)

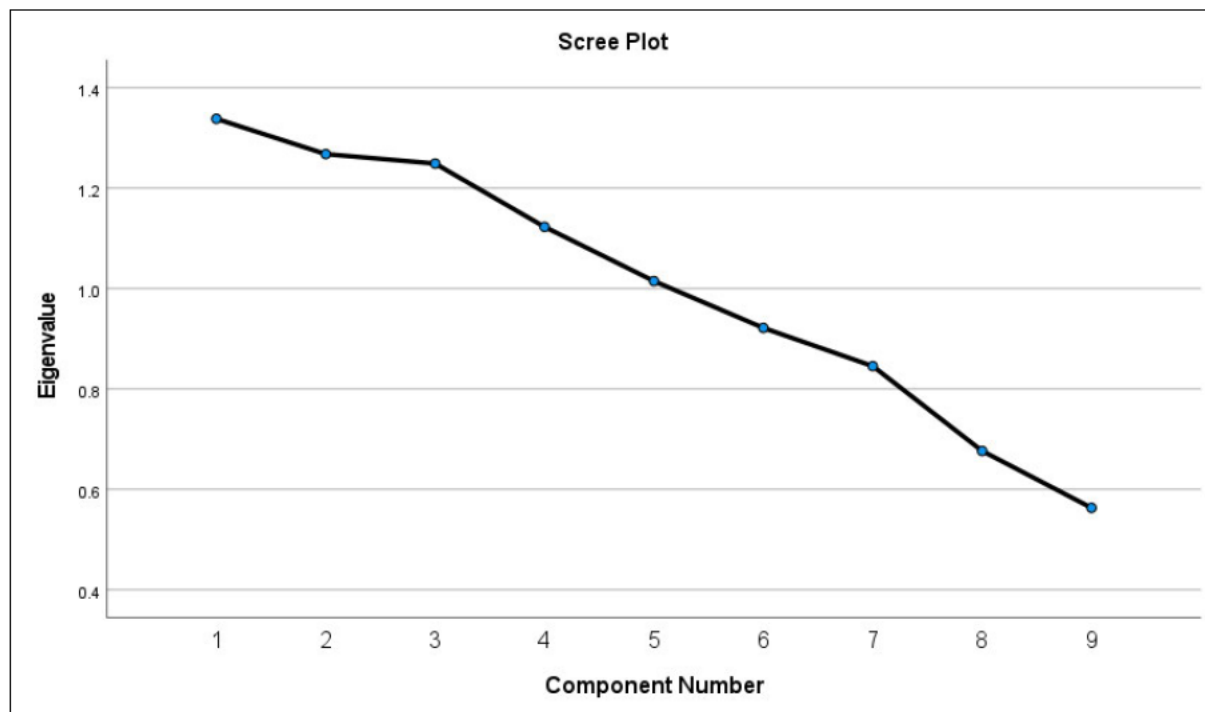


Figure 6.3 Scree plot showing extraction with eigenvalues

Source: Author's Construct (2024)

6.12.4 Key Drivers Influencing Sustainable Student Housing Design in Ghana

Table 6.20 explains the key drivers based on the varimax principal component method. Among the five factors extracted, financial drivers and all-inclusiveness recorded the highest values, indicating significant influence on sustainable student housing design in Ghana. Following these, health, safety, and comfort drivers also ranked highly, particularly when compared to institutional drivers and knowledge-related drivers. In contrast, market demand drivers were found to be negative but significant, suggesting that while they are acknowledged, they do not positively contribute to sustainable design decisions as much as economic and knowledge-related drivers. The analysis revealed that the rotated factors highlighted building design drivers as particularly significant in relation to knowledge-related drivers of sustainable student housing design. These findings imply that financial drivers (FD), health drivers (HD), building design drivers (BD), and economic drivers (ED) are critical influences on student housing investors' decisions to invest in sustainable student housing designs in Ghana. This underscores the importance of these specific drivers in shaping investment strategies and promoting sustainability within the sector.

Table 6.20 Component extraction of Key drivers influencing sustainable student housing design

Rotated Component Matrix ^a					
	Component				
	1	2	3	4	5
FD	0.823				
AD	0.699			0.355	
HD		0.815			
ID		0.564		0.394	
MD			-0.724		
ED			0.643		
END				0.853	

BD					0.876
KD		-0.363	0.471		0.519
Extraction Method: Principal Component Analysis.					
Rotation Method: Varimax with Kaiser Normalization.					
a. Rotation converged in 8 iterations.					

Source: Field survey (2024)

6.12.5 Indicators explaining the total variance explained of extracted factors

This section explains the averages of responses that define the factors extracted in Section 2.1 above, expressed as very high, high, moderate, and low. Among the 37 indicators surveyed, three indicators recorded very high responses related to finance, health, and environmental factors (see Table 6.21). Additionally, 14 indicators reported high responses associated with financial drivers, all-inclusiveness, health, building design, and knowledge-related drivers. Furthermore, 15 indicators attributed the responses to market drivers, government policy drivers, building design drivers, and financial drivers. Lastly, low responses were noted for indicators falling within the economic and knowledge drivers. This distribution of responses highlights the varying degrees of effects that different factors have on sustainable student housing design in Ghana. The prominence of financial and health-related indicators suggests that these areas are critical considerations for stakeholders involved in the development and investment in sustainable student housing.

Table 6.21 Indicators of sustainable student housing design

Variable	Mean	Std. Dev.	Min	Max	Interpretation
ED1	1.943567	1.451781	1	5	Low
ED2	2.611738	1.04775	1	5	Average
ED3	1.778781	1.321867	1	5	Low
ED4	3.647856	0.875852	1	5	High
ED5	2.268623	1.575429	1	5	Moderate
BD1	2.55079	0.766386	1	5	Moderate

BD2	2.986456	1.234789	1	4	Moderate
BD3	3.900677	1.562882	1	5	High
BD4	3.765237	1.50383	1	5	High
GD1	2.379233	0.851255	1	5	Moderate
GD2	3.054176	0.867591	1	5	High
GD3	2.388262	0.72327	1	5	Moderate
GD4	2.89842	0.915464	1	5	Moderate
FD1	4.06772	1.690937	1	5	Very high
FD2	3.857788	1.593284	1	5	High
FD3	3.182844	1.109594	1	5	High
FD4	2.602709	0.977203	1	5	Moderate
FD5	2.399549	0.998052	1	5	Moderate
HD1	2.749436	1.449908	1	5	Moderate
HD2	4.106095	1.260264	1	5	Very high
HD3	3.575621	0.907755	1	5	High
HD4	3.625282	0.798467	1	5	High
AD1	3.374718	1.30086	1	5	High
AD2	3.216704	0.996823	1	5	High
AD3	3.316027	0.990631	1	5	High
AD4	3.255079	0.956256	1	5	High
AD5	3.227991	1.05287	1	5	High
MD1	2.826185	1.046018	1	5	Moderate
MD2	2.318284	1.076405	1	5	Moderate
MD3	2.14447	0.994048	1	5	Moderate
MD4	2.844244	0.977406	1	5	Moderate
KD1	1.952596	1.276311	1	5	Low
KD2	2.82167	1.02117	1	5	Moderate
KD3	3.352144	1.122644	1	5	High
KD4	1.609481	1.137036	1	5	Low
END2	2.738149	1.184005	1	5	Moderate
END3	4.06772	0.529596	1	5	Very high

(source: field data, 2024)

6.12.6 Total variance explained and eigenvalues of indicators influencing drivers of sustainable student housing in Ghana

Table 6.22 explains the principal component analysis of the indicators, using eigenvalues as a benchmark to identify acceptable indicators with values not less than 1. Out of the 37 indicators analyzed, only 17 met this threshold, indicating the significance in the context of sustainable student housing design. These indicators demonstrated high proportional variance, contributing substantially to each of the acceptable factor loadings. This implies that these indicators possess considerable explanatory power in defining the critical reasons investors adopt sustainable student housing design. Conversely, the remaining 20 indicators showed eigenvalues less than 1, suggesting they have limited potential to influence investors' decisions regarding the adaptation of sustainable student housing design. This distinction highlights the importance of focusing on the identified key indicators, as they are more likely to drive effective decision-making and promote sustainability in student housing developments in Ghana.

Table 6.22 Variance explaining extracted indicators of sustainable student housing design

Component	Eigenvalue	Difference	Proportion	Cumulative	Condition
Comp1	2.4357	0.451379	0.0658	0.0658	Accepted
Comp2	1.98432	0.076423	0.0536	0.1195	Accepted
Comp3	1.9079	0.079936	0.0516	0.171	Accepted
Comp4	1.82796	0.074972	0.0494	0.2204	Accepted
Comp5	1.75299	0.123226	0.0474	0.2678	Accepted
Comp6	1.62976	0.07205	0.044	0.3119	Accepted
Comp7	1.55771	0.045982	0.0421	0.354	Accepted
Comp8	1.51173	0.075834	0.0409	0.3948	Accepted
Comp9	1.4359	0.037578	0.0388	0.4336	Accepted
Comp10	1.39832	0.133155	0.0378	0.4714	Accepted
Comp11	1.26516	0.040299	0.0342	0.5056	Accepted
Comp12	1.22486	0.059199	0.0331	0.5387	Accepted

Comp13	1.16566	0.010663	0.0315	0.5702	Accepted
Comp14	1.155	0.096547	0.0312	0.6014	Accepted
Comp15	1.05845	0.042084	0.0286	0.63	Accepted
Comp16	1.01637	0.01602	0.0275	0.6575	Accepted
Comp17	1.00035	0.049257	0.027	0.6845	Accepted
Comp18	0.951093	0.025833	0.0257	0.7102	Rejected
Comp19	0.925259	0.057563	0.025	0.7353	Rejected
Comp20	0.867696	0.018383	0.0235	0.7587	Rejected
Comp21	0.849313	0.044535	0.023	0.7817	Rejected
Comp22	0.804778	0.093969	0.0218	0.8034	Rejected
Comp23	0.710808	0.017095	0.0192	0.8226	Rejected
Comp24	0.693714	0.055489	0.0187	0.8414	Rejected
Comp25	0.638225	0.056939	0.0172	0.8586	Rejected
Comp26	0.581286	0.021929	0.0157	0.8743	Rejected
Comp27	0.559357	0.068743	0.0151	0.8895	Rejected
Comp28	0.490614	0.018656	0.0133	0.9027	Rejected
Comp29	0.471958	0.013083	0.0128	0.9155	Rejected
Comp30	0.458876	0.006489	0.0124	0.9279	Rejected
Comp31	0.452387	0.028967	0.0122	0.9401	Rejected
Comp32	0.42342	0.015107	0.0114	0.9515	Rejected
Comp33	0.408314	0.010186	0.011	0.9626	Rejected
Comp34	0.398128	0.042065	0.0108	0.9733	Rejected
Comp35	0.356062	0.022717	0.0096	0.983	Rejected
Comp36	0.333345	0.036116	0.009	0.992	Rejected
Comp37	0.297229		0.008	1	Rejected

Source: Field survey (2024)

6.12.7 Critical indicators of drivers influencing the adaptation of sustainable student housing in Ghana

This section presents the rotated extraction of variance for acceptable indicators that drive student housing design in Ghana. Based on the rotated extraction, only five components were retained (see Table 6.23). The first component recorded four indicators: ED1 (-0.3065), BD3 (0.4847), FD1

(0.5033), and HD1 (-0.39). Among these, it can be deduced that the high energy cost (FD1) significantly influences student housing investors' intentions to adopt sustainable designs, more so than BD3 (desired space for studying) and ED1 (climate change). The second component recorded four indicators influencing sustainable student housing adaptations: ED5 (0.3221), BD3 (0.3296), FD1 (-0.4515), and FD2 (0.5968). Here, the energy sharing mechanism to students (FD2) demonstrates a higher explanatory power compared to the desired space for students and instances of waste and water efficiency reduction. Although challenges related to high energy costs showed negative values, they raise concerns about the relevance in dictating investors' decisions to adopt sustainable student housing designs in Ghana. The third component revealed positive factor loadings, indicating critical indicators influencing the adaptation of sustainable student housing designs: ED1 (0.3524), ED5 (0.6401), and FD1 (0.4053).

In this cohort, the reduction in waste and water efficiency indicator accounts for approximately 64% of the total factor loadings compared to the high cost of energy (FD1) and climate change factors. This suggests that economic drivers are among the third critical influences on the adaptation of sustainable student housing design in Ghana. The fourth component recorded only two indicators: BD4 (-0.4655) and FD2 (0.4478). This result indicates that the energy sharing mechanism (FD2) is a significant concern for investors, influencing the decisions to adopt sustainable student housing designs. Interestingly, the flexibility in the use of stairs showed an average negative factor loading, raising concerns that may affect investors' decisions regarding sustainable designs. Lastly, the analysis identified three positive significant factor loadings explaining the fifth component, which includes HD1 (0.4693), HD2 (0.3009), and FD2 (0.3314). These results suggest that conditions of thermal comfort from heating and cooling, as well as visual comfort factors like lighting design and natural light, are critical indicators influencing investors

to adopt sustainable student housing designs. However, challenges associated with energy-sharing mechanisms continue to impact decisions regarding sustainability. Considering Table 6.23, it is evident that these rotated indicators have high unexplained contributions, indicating a proportion of indicators not associated with the identified factors. This highlights areas where further investigation may be necessary to fully understand the dynamics influencing sustainable student housing design in Ghana.

Table 76.23 Extracted indicators explaining the drivers of sustainable student housing design

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Unexplained
ED1	-0.3065		0.3524			1.162
ED2						0.9338
ED3						1.492
ED4						0.7185
ED5		0.3221	0.6401			0.5401
BD1						0.5684
BD2						1.144
BD3	0.4847	0.3296				0.7865
BD4				-0.4655		0.8595
GD1						0.6722
GD2						0.6867
GD3						0.4655
GD4						0.6488
FD1	0.5033	-0.4515	0.4053			0.2854
FD2		0.5968		0.4478	0.3314	0.4127
FD3						1.059
FD4						0.8955
FD5						0.9482
HD1	-0.39				0.4693	0.7684
HD2					0.3009	1.132

HD3						0.793
HD4						0.6158
AD1						1.501
AD2						0.8503
AD3						0.9287
AD4						0.8644
AD5						0.8707
MD1						0.9753
MD2						0.8827
MD3						0.8591
MD4						0.7451
KD1						1.541
KD2						0.9146
KD3						1.083
KD4						1.057
END2						1.238
END3						0.2643

Source: Field survey (2024)

6.13 Summary of drivers of sustainable student housing design

This section assesses the drivers of adapting sustainable student housing in Ghana, aiming to achieve Objective Two of the study. Utilizing exploratory factor analysis, the study identified several key factors that significantly influence student housing investors' decisions. Among these, financial drivers emerged as paramount, particularly indicators such as high energy costs and energy sharing mechanisms, which strongly influence investors to adopt sustainable student housing designs. Additionally, health, safety, and comfort indicators—including thermal and visual comfort—were found to be critical in determining the adaptation of sustainable designs. The analysis also highlighted the importance of building design-related factors, such as desired spaces for studying and flexibility in the use of stairs. These design elements are essential for creating functional and comfortable living environments for students. Lastly, economic drivers,

particularly issues related to climate change and the reduction of waste and water efficiency, contributed to the overall framework influencing sustainable student housing adaptations. These findings underscore the multifaceted nature of decision-making among student housing investors in Ghana, emphasizing the interplay between financial considerations, health and comfort needs, and effective building design in promoting sustainability within the sector.

6.14 Barriers of adapting sustainable student housing design in Ghana

This section aims to achieve objective three of the study. The section presents the descriptive of barriers affecting sustainable student design in Ghana. The second section presents exploratory factor analysis results, which includes the test of data sphericity, communalities of factor loadings, total variance explained, scree plots, and indicators of total rotated variance explained. The last section summarizes the chapter.

6.14.1 Descriptive statistics

The study assessed the barriers to sustainable student housing design in Ghana using six defined variables: social, regulation, financial, knowledge, economic, and environmental barriers (see Table 6.24). Among these barriers, the study observed that government regulations regarding the use of sustainable materials and economic factors pose significant threats to the adoption of sustainable student housing design in Ghana. Additionally, responses regarding financial, knowledge, and environmental barriers significantly influence student housing investors' decisions to adopt sustainable designs. However, Table 6.24 indicates that social barriers do not impact student housing investors' decisions concerning sustainable student housing designs in Ghana. This suggests that while other factors present challenges to sustainability efforts, social considerations may not be a primary concern for investors in this context. The findings highlight the need for targeted interventions to address regulatory and economic challenges while also enhancing

knowledge and awareness among stakeholders to facilitate the adoption of sustainable practices in student housing.

Table 6.24 Barriers of sustainable student housing in Ghana

	Minimum	Maximum	Mean	Std. Deviation	Interpretations
ECB	1	5	1.49	0.843	Low
KB	1	5	4.33	1.145	Very high
FB	1	5	3.60	0.763	High
RB	1	5	3.72	0.666	High
SB	1	5	4.45	1.104	Very high
EVB	1	5	3.30	1.241	High
Valid N (listwise)					

Source: Field survey (2024)

6.14.2 Exploratory Factor Analysis of barriers of sustainable student housing design in Ghana

6.14.2.1 Test of data sphericity and suitability

The study assessed the sampling adequacy of respondent (Kaiser-Meyer-Olkin (KMO)). Table 6.25 shows a sampling adequacy of 0.789 which is above the minimum defined threshold of 0.6. This indicated that the sample is adequate to identify the barriers of sustainable student housing design in Ghana. Further, the Bartlett's test of sphericity showed a significant measure of the multivariate normality of the distribution among the barriers of sustainable student housing design in Ghana (Sig. 0.000).

Table 6.25 Test of data sphericity and suitability of objective 3

KMO and Bartlett's Test			
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.			0.789
Bartlett's Test of Sphericity	Approx. Chi-Square		235.364
	df		120
	Sig.		.000
Determinant			

Source: Field survey (2024)

6.14.2.2 Data reliability analysis

Table 6.26 describes the data reliability of the study. The analysis showed a combined Cronbach Alpha of 0.842 which is good and high to explain the reliability and validity of the construct describing the barriers of sustainable student housing design in Ghana.

Table 6.26 Data reliability analysis of objective 3

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.846	.842	22

Source: Field survey (2024)

6.14.2.3 Communalities of factor loadings

This section describes the communalities in factor loadings and the strength of each barrier. Test of communality shows that SB1-SB5 contributed positive loadings above 0.3 that describes the strength of social barriers in sustainable student housing design. Similarly, the study found positive loadings among regulation barriers which above 0.3 and is suitable for factor analysis. Aside, financial drivers recorded the highest largest positive loadings among others (see table 6.27). Knowledge barriers on the other hand recorded high and positive loadings which has the capacity to affect student housing investors decision to adapt sustainable student housing designs in Ghana.

However, the study did not record any significant response to economic and environmental barriers. This was due to the fact that student housing investors classify these under financial and social barriers.

Table 6.27 Communalities among indicators

Communalities		
	Initial	Extraction
SB1	1.000	0.508
SB2	1.000	0.671
SB3	1.000	0.485
SB4	1.000	0.661
SB5	1.000	0.507
RB1	1.000	0.637
RB2	1.000	0.631
RB3	1.000	0.449
RB4	1.000	0.551
FB1	1.000	0.812
FB2	1.000	0.501
FB3	1.000	0.675
FB4	1.000	0.783
KB1	1.000	0.563
KB2	1.000	0.516
KB3	1.000	0.635
Extraction Method: Principal Component Analysis.		

Source: Field survey (2024)

6.14.3 Factor loadings and total variance explained of barriers of sustainable student housing design in Ghana

This section describes the factor loadings and variance explained using the scree plot (Figure 6.4) and Table 6.28. Using the principal component method through the unrotated factor loadings extraction, the study recorded 7 barriers with eigenvalues higher than 1 (see Figure 6.4). This

implies the first 7 factors explains critical barriers of sustainable student housing design. However, the remaining 9 factors explains the small proportion of variability of responses on the barriers of student housing design and are likely to be classified as unimportant. Overall, the 7 variables explain 59.9% of variations in data.

The Kaiser criterion of retaining the critical barriers of sustainable student housing design were use. The first factor retained eigenvalues values of 11.109, which explained 11.109. % cumulative extraction sums of squared loadings variances. Also, the second factor recorded a cumulative sum of squared loadings of 20.757% above the eigenvalues of the variables recorded in the first factor. The third factor also reported high cumulative values of 30.240% higher than factor 2 (see table 6.28). The fourth, fifth, sixth, and seventh cumulative sums of squared of factor loadings shows 38.409%, 46.128, 53.186%, and 59.899. these explains sufficient evidence of the influence of the indicators in determining investors decisions on the barriers of sustainable student housing in Ghana.

Table 8 Total variance of barriers of sustainable student housing design

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.777	11.109	11.109	1.777	11.109	11.109	1.569	9.807	9.807
2	1.544	9.648	20.757	1.544	9.648	20.757	1.551	9.694	19.501
3	1.517	9.483	30.240	1.517	9.483	30.240	1.470	9.187	28.688
4	1.307	8.170	38.409	1.307	8.170	38.409	1.333	8.330	37.018
5	1.235	7.719	46.128	1.235	7.719	46.128	1.297	8.107	45.125
6	1.129	7.057	53.186	1.129	7.057	53.186	1.206	7.538	52.663
7	1.074	6.713	59.899	1.074	6.713	59.899	1.158	7.236	59.899
8	.978	6.116	66.015						
9	.935	5.841	71.856						
10	.863	5.393	77.249						
11	.750	4.686	81.935						

12	.697	4.359	86.294						
13	.612	3.825	90.119						
14	.597	3.731	93.850						
15	.513	3.203	97.054						
16	.471	2.946	100.000						
Extraction Method: Principal Component Analysis.									

Source: Field survey (2024)



Figure 6.4 Scree plot showing barriers of sustainable student housing design

Source: Field survey (2024)

6.14.4 Critical indicators explaining the barriers of sustainable student housing design

This section presents the varimax rotation results to determine the seven key barriers to sustainable student housing design (see Table 6.29). The rotated variables indicate that RB1 and FB2 are the main barriers influencing decisions regarding sustainable student housing design, with factor loadings of KB1 = 0.741 and FB2 = 0.688. This implies that a lack of knowledge about the profitability and cost of indoor sustainable student housing, along with the high cost of building

materials, are critical barriers affecting investors' decisions. Furthermore, the study identified three key indicators as the second barrier impacting sustainable student housing design: RB4 (0.685), KB3 (0.612), and SB1 (0.595). According to student housing investors, the lack of energy audits and assessments, insufficient knowledge of environmental effects, and the complexity of sustainable designs also hinder the intentions to adopt sustainable student housing. Table 6.29 also reports high positive values for the rotation of indicators related to barriers influencing sustainable student housing design. Notably, significant rotated loadings of SB2 (0.762) and SB3 (0.517) represent the third most influential barriers. These results are linked to perceptions regarding long product lifecycles for buildings and materials, as well as technical challenges related to material recovery that may affect sustainable student housing design. Moreover, the study recorded one positive and two negative factor loadings representing the fourth factor influencing decisions toward sustainable student housing design in Ghana (KB2 = 0.731, RB2 = -0.490, RB1 = -0.398). These results suggest that while obstructive laws and regulations and a lack of a consistent regulatory framework present negative influences, they still significantly predict contributions to adopting sustainable student housing design in Ghana. Notably, inadequate appropriate skills for managing sustainable designs—such as communication, awareness, experience, negotiation, leadership, and lateral thinking—(KB1 = 0.731) form the highest component in this cohort. This indicates that approximately 73% of variability in responses supports this as a key barrier affecting decisions to adopt sustainable student housing in Ghana. Additionally, three key drivers formed the fifth barrier to sustainable student housing design. According to variance extracted values, KB4 (0.754) and SB4 (0.674) show largely positive contributions to barriers related to sustainable student housing. However, one factor recorded a negative loading for the fifth barrier: SB5 (-0.403). This implies that while investors' knowledge about building lifecycle-efficient energy

solutions and running costs contributes positively to the decision-making regarding sustainable designs, a lack of market demand for sustainable buildings does not significantly influence these decisions. Financial barriers were identified as the sixth highest indicator influencing adaptation decisions for sustainable student housing designs in Ghana.

Table 6.29 shows that FB1 (0.843) recorded positive contributions to investors' decisions compared to FB3 (-0.451). Investors perceive upfront investment costs in purchasing sustainable building materials as a significant positive indicator. However, they also view sustainable student housing designs as expensive and underfunded due to the largely private sector-led nature, which affects the investment decisions. Finally, the study found a high positive rotated factor loading for FB4, attributed to long payback periods and investment risks associated with adopting sustainable student housing designs. This represents the seventh highest barrier affecting adaptation decisions in this context. Interestingly, these results suggest that student housing investors may lack sufficient knowledge about what constitutes sustainability in the investment choices.

Table 6.29 Factor loadings of indicators explaining the barriers of sustainable student

Rotated Component Matrix^a							
	Component						
	1	2	3	4	5	6	7
KB1	.741						
FB2	.688						
RB4		.685					
KB3		.612					
SB1		.595					
SB2			.762				
SB3			.517				
KB2				.731			
RB2				-.490			

RB1				-.398			
KB4					.754		
SB4					.674		
SB5					-.403		
FB1						.843	
FB3						-.451	
FB4							.873
Extraction Method: Principal Component Analysis.							
Rotation Method: Varimax with Kaiser Normalization.							
a. Rotation converged in 24 iterations.							

Source: Field survey (2024)

6.15 Summary of barriers of sustainable student housing design

The chapter analyzed the barriers of sustainable student housing design in Ghana. According to the study, social, financial, knowledge, and regulatory barriers are critical barriers of adopting sustainable student housing design. Technically, 7 indicators described the barriers influencing sustainable student housing design. Among these cohorts, perception of upfront investment costs in purchase of sustainable building materials, long payback period and investment risks, investors knowledge about building lifecycle-efficient energy solutions and running cost, the lack of knowledge on profitability and cost of indoor sustainable student housing, long product lifecycles (buildings and materials), inadequate appropriate skills for managing sustainable student housing design (e.g. communication, awareness, experience, negotiation, leadership, and lateral thinking, and lack of consistent regulatory framework and high cost of building materials are critical barriers affecting investors decisions to invest in sustainable student housing design.

6.16 Student behavioural control and energy use in university student housing in Ghana

This chapter aims to achieve chapter 4 of the study. The section presents and analyze results on student behavioral control and its influence on energy consumption in student housing. Section 4.1

describes the level of awareness of sustainable energy consumption in student housing. The second section analysis the attitude of students towards building control systems in student housing. section 4.3 describes the factors and effects of drivers of student behaviour towards energy consumption in university student housing in Ghana.

6.16.1 Level of awareness of sustainable energy in student housing

Table 6.30 describes the level of awareness of sustainable energy in student housing in Ghana. The levels were analysed based on responses above the average mean. According to results only 4 out of 9 indicators recorded means above the average mean score. These include LAW7, LAW5, LAW6, and LAW1. According to the description, this can be interpreted that students largely understand the benefit and consequences of using sustainable energy. Aside, students understand sustainable energy as a solution to natural resource depletion, energy saving has long-term effect on future generation, Energy efficiency have effects on global warming and greenhouse effect. On the flipside, 5 indicators recorded weak levels of awareness of energy sustainability in student housing in Ghana. These include, understand that energy saving affects productivity and comfort, understanding the level of information on sustainable energy use, understanding that sustainable energy use influences the building performance, understanding the knowledge on practicing water and electricity energy saving in the building, and the availability of energy sustainable buildings on university campus. Following the above, it can be deduced that students largely understand energy sustainability as a concept, but not its relation to student housing which may have ripple effects on energy use behaviours.

Table 6.30 Construct Mean Std. Deviation Minimum Maximum interpretations

Construct	Mean	Std. Deviation	Minimum	Maximum	interpretations
LAW1	2.36	1.374	1	5	Support
LAW2	2.05	1.108	1	5	Do not support
LAW3	2.18	1.098	1	5	Do not support
LAW4	2.25	1.053	1	5	Do not support
LAW5	2.58	1.26	1	5	Support
LAW6	2.57	1.373	1	5	Support
LAW7	2.68	1.278	1	5	Support
LAW8	2.19	1.33	1	5	Do not support
LAW9	1.79	1.79	1	5	Do not support
Average Mean Scores			2.29		

Source: Field survey (2024)

(Note: LAW denotes: Levels of Awareness)

6.16.2 Student Attitude Towards Indoor Environmental Energy Sustainability in Ghana

This section presents and analyzes students' attitudes toward building control systems in university student housing in Ghana. The study conceptualized the indicators to include appliances management and gadget control, outdoor visual and thermal control, indoor visual and thermal control, and building services control. Using the Relative Importance Index (RII) analytical approach, the study ranked the weights based on cumulative responses related to the scale of very high impact (5), high impact (4), moderate impact (3), low impact (2), and very low impact (1) on indoor environmental energy sustainability. Table 6.31 indicates that students' attitudes toward electrical appliances management and gadget control received very low rankings regarding energy sustainability in student housing. For example, students showed weak attitudes toward thermostat control for air conditioning (RII = 0.27) and the use of low-energy labeled electrical gadgets (RII = 0.30).

It was also observed that leaving energy appliances on standby was common among students. In contrast, students demonstrated a strong attitude toward using energy-saving bulbs, which received a high score of 5. This suggests that students are more aware of the benefits of energy-saving bulbs compared to electrical gadgets, raising concerns about gadget regulations within student housing management and the Energy Commission. Regarding outdoor visual and thermal control, student housing managers expressed high satisfaction with students' attitudes toward closing window blinds or shades during indoor and outdoor activities. However, students' attitudes toward using artificial lighting during the day were ranked lower ($RII = 0.56$), indicating a sixth-place ranking. There was also significant dissatisfaction with students' attitudes toward controlling door and window tightness, which has implications for air conditioning usage. Moreover, Table 6.31 shows that indicators related to indoor thermal and visual comfort did not contribute to high satisfaction levels. According to student housing managers, attitudes such as turning off air conditioning when opening windows during the rainy season ($RII = 0.53$), switching off lights when not in use ($RII = 0.51$), and turning on air conditioning when windows are open during the dry season ($RII = 0.45$) reflect a lack of understanding among students regarding appropriate air conditioning usage. Other factors may influence these attitudes, which will be explored in the next section.

Lastly, the study found a high level of satisfaction regarding building services control indicators related to indoor energy sustainability in Ghana. Among these indicators, using water closets during flushes ($RII = 0.68$) ranked as the second most satisfied attitude among students. Turning off taps while brushing teeth or washing hands ($RII = 0.62$) was ranked third, while using showers instead of bathing with buckets ($RII = 0.55$) was ranked sixth. Overall, it can be deduced that student attitudes toward building services control do not significantly impact indoor energy

sustainability in Ghana. The next section will describe the drivers and implications of student behavior regarding energy consumption in student housing.

Table 6.31 critical building control features that influence energy consumption

Variable definition	Indicators	Construct	1	2	3	4	5	TOTAL	RII	Rank
Appliance management and gadget control										
	Washing machine cautiously	AMI	74	0	108	212	0	394	0.48	9
	Leaving energy appliances on standby mode	AM2	92	0	32	184	9	317	0.39	11
	Using low-energy labelled electrical gadgets	AM3	128	0	60	60	0	248	0.30	13
	Thermostat control approach for air conditioning in the building	AM4	72	132	15	0	0	219	0.27	14
	Using energy-saving bulbs	AM5	48	48	57	168	150	471	0.58	4
Outdoor visual and thermal control										
	Closing window blinds or shade during indoor or outdoor activities	OVT1	13	10	21	412	175	631	0.77	1
	Controlling doors/windows airtightness	OVT2	61	184	15	0	25	285	0.35	12
	Using artificial lighting in a day	OVT3	0	192	93	48	120	453	0.56	5
Indoor visual and thermal control										
	Putting air-conditioner off when opening windows during rainy season	IVT1	29	128	69	108	100	434	0.53	7
	Putting air-conditioner on when windows open during the dry season	IVT2	51	110	114	0	95	370	0.45	10
	Turning off lights if they're not in use or needed	IVT3	5	190	111	68	45	419	0.51	8
Building services control										
	Usage of WC during flush	BSC1	32	0	51	400	70	553	0.68	2
	Turning the tap off when brushing teeth or washing hands	BSC2	13	20	312	92	65	502	0.62	3
	Using showers instead of bathing with buckets	BSC3	74	0	90	52	230	446	0.55	6

Source: Field survey (2024)

6.16.3 Determining the impact of drivers of student's behaviours towards energy consumption

6.16.3.1 Model assessment and evaluation

The model assessment criteria involved testing the satisfactory levels of the variances that explained the models. Second, the section presents and interpret the construct validity and discriminant validity. The final section explains the collinearity of the data.

6.16.3.2 Construct validity

Construct validity and reliability was assessed based on the Average Variance Explained in Table 6.32. The AVE assessment generated showed very high values for SOD indicators. Similarly, it can be evident that COD indicators scored values but above the recommended threshold of 0.50. Considering these results, it can deduce that the variables recorded AVE values higher than the recommended minimum point. This implies that validity of the factors and its indicators are high and satisfactory for predictions.

Table 6.32 construct validity for model 2

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
BFT	0.888	0.891	0.923	0.751
COD	0.813	0.848	0.871	0.628
ECD	0.933	0.933	0.948	0.753
PCD	0.890	0.893	0.924	0.752
PHD	0.929	0.929	0.950	0.825
PSD	0.905	0.907	0.930	0.727
SOD	0.920	0.923	0.943	0.806

Source: Field survey (2024)

6.16.3.3 Discriminant validity

Table 6.33 assesses the correlations that exist among the contract as a means of construct assessment. Using the heterotrait-monotrait (HTMT) ratio of the correlations, it can be observed that COD recorded similarity values 0.790 when compared with BFT. However, it looks lower than the minimum threshold (0.85 or 0.90) because of the distinct nature of the variables. Similar, ECD and COD recorded less similarity as HTMT values were closer of the acceptable minimum point. PHD and PCD did not show similarity with COD. However, PCD recorded high correlation

values above the minimum threshold when compared with ECD (0.933). Overall, PSD and COD recorded the strongest similarity. However, because the heterotrait-monotrait (HTMT) matrix is not large than the AVE values in Table 6.33 below, it can be interpreted that the model is suitable.

Table 6.33 Discriminant validity of model 2

Construct	BFT	COD	ECD	PCD	PHD	PSD	SOD
BFT							
COD	0.790						
ECD	1.000	0.806					
PCD	1.020	0.785	0.933				
PHD	0.958	0.743	1.054	0.860			
PSD	1.014	0.851	1.055	1.021	1.004		
SOD	1.038	0.723	1.017	0.880	1.027	0.959	

Source: Field survey (2024)

6.16.3.4 Redundancy analysis

The redundancy analysis describes the collinearity of the variables. This is based to determine whether a single-indicator defines the each of the construct in the model. Using the Variance Inflation Factor (VIF), the study recorded higher VIF values in EC3, EC4, EC5, and PSD3 (see table 6.34). This is above the minimum threshold of $\leq 3 \leq 4$. This implies that these indicators share similar thoughts on the effects of student behaving drivers on energy consumption in Ghana. However, indicators with lower VIF values less than or equal to 3 represents diverse contributions of the indicators towards energy consumption.

Table 6.34 redundancy analysis of model 2

Constructs	VIF	Interpretations
BF3	3.113	Moderate collinearity
BFT1	1.712	Very low collinearity
BFT2	2.752	Low collinearity
BFT3	2.833	Low collinearity
COD1	1.256	Very low collinearity
COD2	2.169	Low collinearity
COD3	2.401	Low collinearity
COD4	2.308	Low collinearity
EC1	3.159	Moderate collinearity
EC2	3.445	Moderate collinearity
EC3	4.472	Very high
EC4	4.150	Very high
EC5	4.140	Very high
EC6	1.656	Very low collinearity
PCD1	2.753	Low collinearity
PCD2	2.958	Low collinearity
PCD3	2.788	Low collinearity
PCD4	1.908	Very low collinearity
PHD1	2.895	Low collinearity
PHD2	3.443	Moderate collinearity
PHD3	3.955	Moderate collinearity
PHD4	3.314	Moderate collinearity
PSD1	3.843	Moderate collinearity
PSD2	3.732	Moderate collinearity
PSD3	4.032	Very high
PSD4	2.641	Low collinearity
PSD5	2.695	Low collinearity
SOD1	3.056	Moderate collinearity
SOD2	3.070	Moderate collinearity
SOD3	3.145	Moderate collinearity
SOD4	2.953	Low collinearity

Source: Field survey (2024)

6.16.4 Model assessment and fit

6.16.4.1 Model reliability

This section describes the model fit based on data reliability and effect size values. R^2 statistics values were used to explain the data reliability. Table 6.35 showed a plausible value ($R^2=0.972$)

which translate into 97.2% explanation power that describes the drivers that influences student energy use behaviours. Similarly, the study recorded acceptable values of ECD ($R^2=0.829$) that explains about 82.9% explanatory powers of energy consumption in student housing. Overall, these explanatory powers are above the minimum threshold of 0.25 as weak.

Table 6.35 Reliability results of model 2

Construct	R-square	R-square adjusted	Conditions
BFT	0.972	0.971	Accepted
ECD	0.829	0.828	Accepted

Source: Field survey (2024)

6.16.5 Model effects size

Using the f^2 statistics to explain the significant relationship among construct, estimates of the effects size of the construct showed a high value for BFT -> ECD (4.853) (see table 6.36). Thus, cumulative value higher than the recommended minimum point of 0.35 as high, 0.02 as medium, and 0.15 as small. Considering the values recorded in BFT -> ECD (4.853), PHD -> BFT (0.516), PCD -> BFT (0.306), and SOD -> BFT (0.2785), it can be deduced that it has a substantial contribution to the relationship established in the model. However, COD -> BFT (0.001) and PSD -> BFT (0.143) recorded smaller substantial contribution to the relationships in the construct (see table 6.36). This implies that these variables limitedly explain the variance of BF factors that influences energy consumption in student housing in Ghana.

Table 6.36 Model effect size of model 2

Construct	f-square	Conditions
BFT -> ECD	4.853	Accepted
COD -> BFT	0.001	Rejected
PCD -> BFT	0.306	Accepted
PHD -> BFT	0.516	Accepted
PSD -> BFT	0.143	Rejected
SOD -> BFT	2.785	Accepted

Source: Field survey (2024)

6.16.6 Model selection criteria

6.16.6.1 Model fit selection 1

The study used the Standardize Root Mean Square Residuals (SRMR) to determine the goodness of fit of the model. Table 6.37 showed SRMR values (SRMR=0.126) for saturated and SRMR=0.133 values of the estimated model. Overall, it can be deduced that these values fall above the recommended minimum point of 0.1 or 0.8. Aside, the BIC (Bayesian information criterion) witnessed higher values in BFT (-847.104) and ECD (-424.650) (see table 6.38). However, these values exceed the threshold of -270 and -150. This implies that the model is fit for the study

Table 6.37 Goodness-of-fit test

Criteria	Saturated model	Estimated model
SRMR	0.126	0.133
d_ ULS	7.832	8.759

(Source: field data, 2024)

Table 6.38 BIC (Bayesian information criterion) of model 2

Variables	BIC (Bayesian information criterion)
BFT	-847.104
ECD	-424.650

Source: Field data (2024)

6.16.6.2 Model fit selection 2

This section checks the robustness of the model using the relative fit index and non-centralised indices. Table 6.39 reports relative fit index; Tucker-Lewis Indices-TLI, Normed fit index (NFI), and Incremental Fit, and non-centralised indices; comparative Fit Index (CFI) and the Root Mean Square Error of Approximation (RMSEA). Table 1 shows that all relative fits indices for TLI and CFI were 0.853 which is above the required threshold 0.80. Also, CFI reported 0.912 estimates high than 0.90 as supported by Hu and Bentler (1980). Other fit results; RMSEA also recorded a satisfactory model fit, thus 0.065. Similarly, NFI index findings was also good (see table 6.39)

Table 6.39 relative fit index and non-centralised indices

Model fit	Threshold	Estimated
Tucker-Lewis Index-TLI	> 0.80 (Bentler & Bonnet, 1980)	0.853
Comparative Fit Index	> 0.90 Hu and Bentler (1999).	0.912
Incremental Fit Index-IFI	> 0.90 (Bentler & Bonnet, 1980)	0.904
Root Mean Square Estimator of Approximation-RMSEA	0.08 and 0.10 (mediocre model fit), < 0.08 (MacCallum et al., 1996) < 0.07, as good (Steiger, 2007)	0.065
Normed fit index-NFI	> 0.90 (Bentler & Bonnet, 1980)	0.909

Source: Field survey (2024)

6.16.7 Model results

6.16.7.1 Descriptive and significant power of constructs

Table 6.40 and figure 6.5 present results on the significant influence of drivers of student housing energy use on student behaviour in Ghana. the results show that all the drivers have significant influence on student behaviour except COD drivers. Aside, SOD drivers recorded higher sample means (Mean=0.983) which shows a high response towards SOD influence on student housing behaviour. Also, BFT drivers showed second highest means in determining student energy

consumption in Ghana. PHD showed negative but significant means to behavioral factors. This implies that the response on PHD have negative values but can positively correlate with other drivers in determining the direct, indirect, and total effect of the model. Overall, the construct defining the influence of the drivers of student housing energy use have significant influence on students' behaviours.

Table 6.40 Descriptive and significant power of model 2

Construct	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics ((O/STDEV))	P values
BFT -> ECD	0.910	0.911	0.013	69.229	0.000
COD -> BFT	0.008	0.008	0.019	0.406	0.684
PCD -> BFT	0.269	0.269	0.033	8.212	0.000
PHD -> BFT	-0.577	-0.575	0.053	10.851	0.000
PSD -> BFT	0.326	0.324	0.052	6.259	0.000
SOD -> BFT	0.983	0.983	0.044	22.316	0.000

Source: Field Survey (2024)

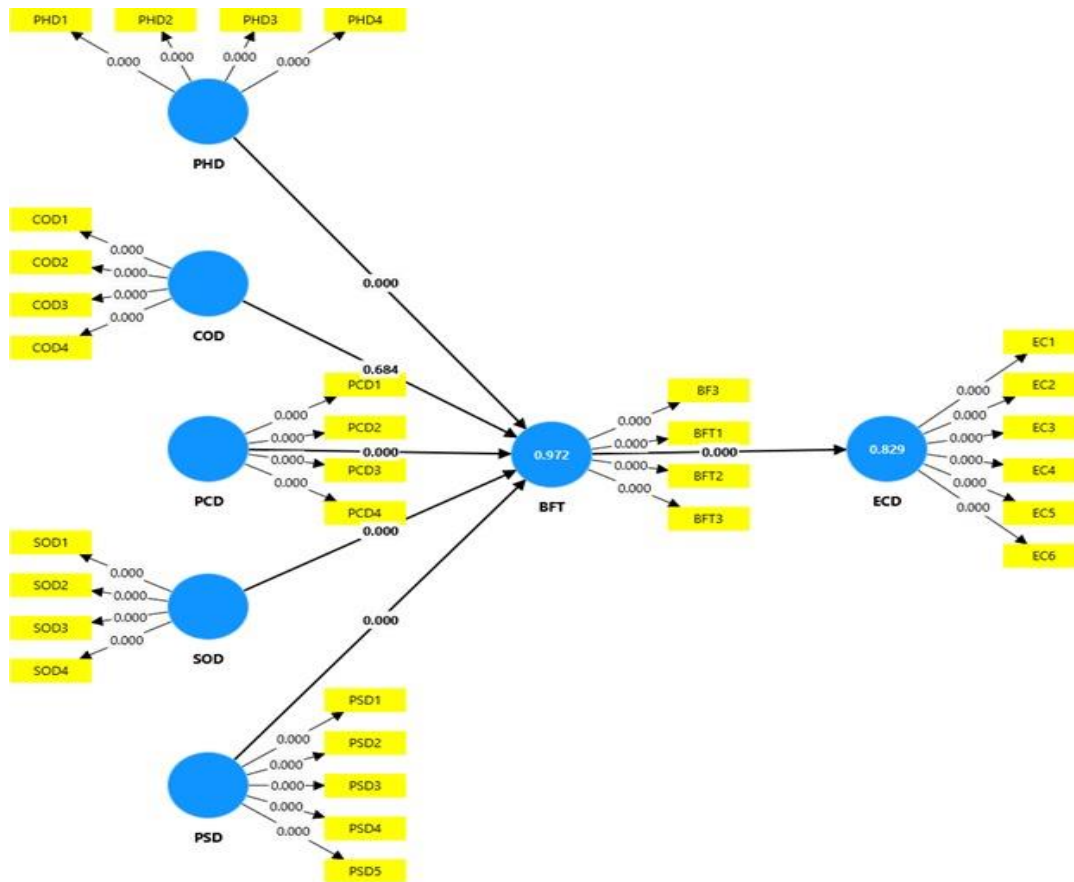


Figure 6.5 hypothetical significance of model 2

Source: Author's Construct (2024)

6.16.8 Relationship between the drivers of student energy use and energy consumption

Table 6.41 explains the sample means and P-values of the COD, PCD, PHD, PSD, and SOD drivers on BFT and ECD. The results indicate significant P-values (less than 0.05) for all drivers except COD, suggesting that COD drivers have a weaker relationship with energy consumption in student housing. Overall, the study deduces that SOD establishes the highest relationship determining energy consumption in student housing, with a sample mean of 0.895. The PSD and PCD drivers follow as the second and third drivers showing positive relationships with the energy consumption constructs. In contrast, PHD indicators represent the fourth driver, indicating a negative

relationship with energy consumption constructs. This suggests that the determinants of energy consumption have an inverse relationship with the drivers of PHD indicators.

Table 6.41 Relationship between the energy consumption constructs of model 2

Construct	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (O/STDEV)	P values
COD -> BFT -> ECD	0.007	0.007	0.017	0.406	0.684
PCD -> BFT -> ECD	0.245	0.245	0.030	8.299	0.000
PHD -> BFT -> ECD	-0.526	-0.523	0.047	11.245	0.000
PSD -> BFT -> ECD	0.297	0.296	0.048	6.189	0.000
SOD -> BFT -> ECD	0.895	0.895	0.038	23.322	0.000

Source: Field survey (2024)

6.16.9 Model results on the effects of student behaviour on energy consumption in student housing

6.16.9.1 Direct effects

Table 6.42 and Figure 6.6 illustrate the five key drivers of student energy use and the direct effects on behavioral factors. The results, represented as path coefficient values in Figure 6.6, indicate that SOD recorded the highest direct effect on student behaviors, with a coefficient of 0.970. Following this, PSD contributed approximately 32.0% to behavioral factors, while PCD accounted for 27.9%. In contrast, PHD exhibited a negative effect of -56.8% on behavioral factors. Overall, the drivers of student energy use influence the behavioral factors by 97.2%, suggesting that the factors affecting students' energy use largely shape the behavioral intentions. Regarding the contributions of these behavioral factors toward energy consumption, the model demonstrated significantly high effects on energy consumption in student housing, as shown in Table 6.42. These findings pinpoint the critical role that various drivers play in influencing student behaviors related

to energy consumption, highlighting the need for targeted interventions to promote sustainable energy practices within university settings.

Table 6.42 direct effects of behavioural factors on energy consumption

Constructs	Path coefficients
BFT -> ECD	0.911
COD -> BFT	0.009
PCD -> BFT	0.279
PHD -> BFT	-0.568
PSD -> BFT	0.320
SOD -> BFT	0.970

Source: Field survey (2024)

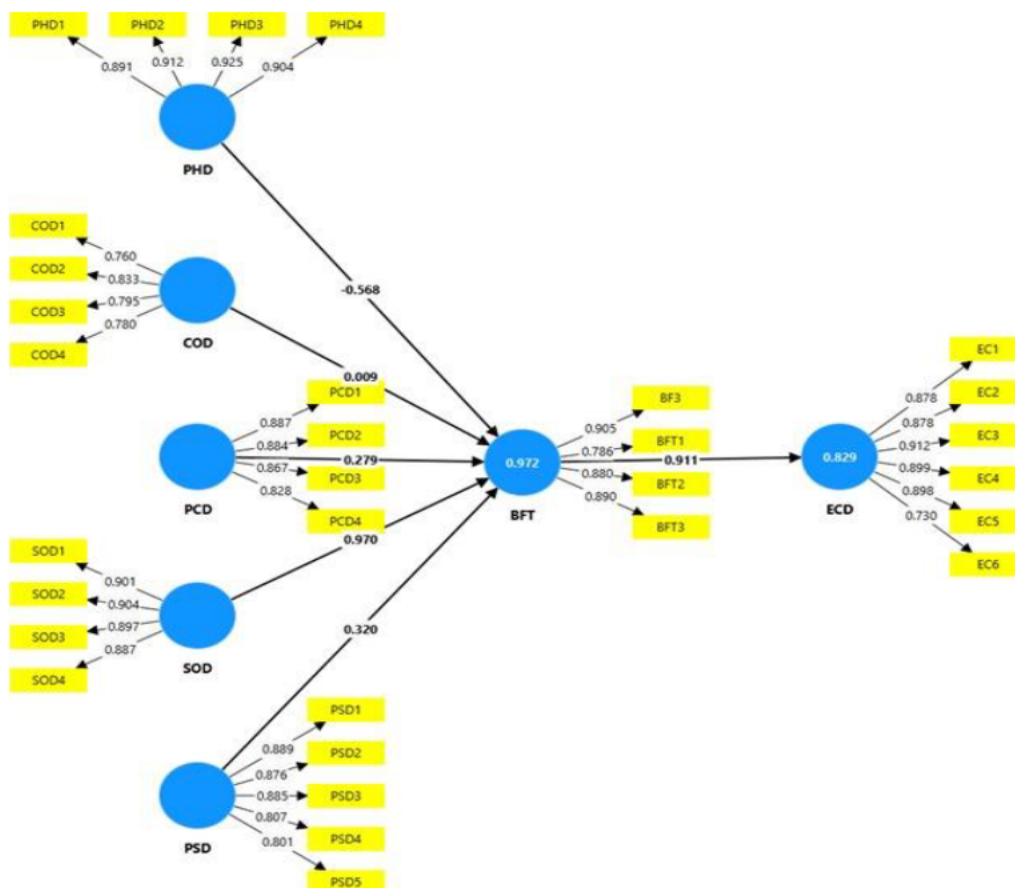


Figure 6.6 Path coefficient of model 2

Source: Author's construct (2024)

6.16.9.2 Specific indirect effect

This section assesses the indirect contributions of student energy use factors on energy consumption in Ghana. Table 6.43 indicates that the SOD driver contributes approximately 88.3% to energy consumption in student housing. Additionally, it is observed that the pathways PSD → BFT → ECD and PCD → BFT → ECD recorded less indirect effects on energy consumption, implying that increases in the PSD and PCD factors indirectly raise energy consumption by 29.1% and 25.5%, respectively. Conversely, the PHD driver reported negative effects on energy consumption, suggesting an inverse relationship between PHD and ECD. Although these negative findings may seem concerning, they can serve as a predictor for high energy consumption when not effectively managed. Furthermore, among all constructs, COD recorded insignificant indirect effects on energy consumption in student housing. This could indicate that students perceive COD as management-related drivers influencing energy consumption in Ghana. Overall, these findings show the complex relationship between various factors influencing energy consumption in student housing, emphasizing the need for targeted strategies to manage both direct and indirect influences effectively.

Table 96.43 Indirect effect of model 2

Constructs	Specific indirect effects	Interpretation
COD → BFT → ECD	0.008	Rejected
PCD → BFT → ECD	0.255	Accepted
PHD → BFT → ECD	-0.517	Accepted
PSD → BFT → ECD	0.291	Accepted
SOD → BFT → ECD	0.883	Accepted

Source: Field survey (2024)

6.16.9.3 Total effects of indicators of drivers of student behaviour on energy consumption

This section presents the total effects of student energy use factors and behavioral factors on energy consumption in Ghana. With respect to behavioral factors, students' attitudes towards energy use contributed the highest effects on energy consumption in student housing, accounting for 90.5%. In this context, students' perceived behavioral control and behavioral intentions also reported significant values, although they were lower than students' attitudes. Conversely, personal norms recorded the lowest contribution to energy consumption. Earlier findings indicated insignificant contributions of contextual drivers on student behaviors and energy consumption. However, the total contributions of contextual indicators revealed that COD2 (ventilation) in student housing had high effects on energy consumption, despite not being a directly or indirectly significant factor compared to COD1 (insulation), COD3 (heating systems), and COD4 (building orientation). Additionally, psychological drivers of student energy use behaviors significantly influenced energy consumption in Ghana. Table 6.44 shows that all PCD indicators demonstrated positive significance towards energy consumption. Among these indicators, visual comfort, thermal comfort, and health and safety had very high effects on energy consumption compared to acoustic comfort. The substantial contribution of visual comfort aligns with earlier findings regarding the negative impact of window glazing on heating and cooling. High thermal comfort can be attributed to inadequate indoor circulation and floor span issues identified previously. Despite the impact of psychological drivers, physical indicators also showed high contributions to energy consumption. The study tested the effects of PHD1 (temperature), PHD2 (noise), PHD3 (room illumination), and PHD4 (odor) on energy consumption in student housing. All these indicators exhibited positive significance, with noise levels (92.5%) and room illumination (91.2%) having a more substantial impact on energy consumption compared to temperature and odor. The study also observed that

physiological drivers—PSD1 (age), PSD2 (gender), PSD3 (health condition), PSD4 (activity level in the building), and PSD5 (students' income levels)—are positive and significant indicators influencing energy consumption in Ghana. Students indicated that age and health conditions within the building significantly affect energy consumption, suggesting that the age of students and lack of maintenance in student housing have a considerable impact. Finally, social drivers emerged as the highest factor influencing energy consumption in Ghana. According to PLS-SEM results, indicators such as SOD1 (number of students per room, sleeping hours, studying hours), SOD4 (window opening), SOD3 (clothing changes), and SOD2 (social and personal influence) were significant contributors. Most respondents identified the number of students per room, along with sleeping and studying hours, as critical indicators affecting energy consumption in student housing. This implies that high occupancy rates and room selection compositions pose threats to energy consumption by putting pressure on indoor facilities and energy systems. Overall, the PLS-SEM analysis indicated that students' attitudes increase energy consumption by over 10% in student housing in Ghana. This underscores the implications of energy consumption on sustainability within student housing that require serious attention.

Table 6.44 Total effects of model 2

Observed variables	BFT	COD	ECD	PCD	PHD	PSD	SOD	p-values
BFT4	0.905							0.000
BFT1	0.786							0.000
BFT2	0.880							0.000
BFT3	0.890							0.000
COD1		0.760						0.000
COD2		0.833						0.000
COD3		0.795						0.000
COD4		0.780						0.000
EC1			0.878					0.000
EC2			0.878					0.000
EC3			0.912					0.000
EC4			0.899					0.000
EC5			0.898					0.000
EC6			0.730					0.000
PCD1				0.887				0.000
PCD2				0.884				0.000
PCD3				0.867				0.000
PCD4				0.828				0.000
PHD1					0.891			0.000
PHD2					0.912			0.000
PHD3					0.925			0.000
PHD4					0.904			0.000
PSD1						0.889		0.000
PSD2						0.876		0.000
PSD3						0.885		0.000
PSD4						0.807		0.000
PSD5						0.801		0.000
SOD1							0.901	0.000
SOD2							0.904	0.000
SOD3							0.897	0.000
SOD4							0.887	0.000

Source: Field survey (2024)

CHAPTER SEVEN

FOCUS GROUP DISCUSSION RESULTS

7.1 Introduction

This section presents the results emanated from focus group discussion based on experts' view on sustainable student housing design in Ghana. The section includes; understanding of sustainable student housing design, requirements, drivers, and barriers of sustainable student housing design.

7.2 Expert's understanding of sustainable student housing design

The understanding of the concept 'sustainable student housing' was presented in different form. According to some experts, sustainable student housing design is technically aimed at energy efficiency. Critical focus of ensuring energy efficiency student housing was based on the understanding of optimizing user's space of the students due to the large numbers that usually occupy one room. Aside, it was important to understand that increasing the use HAVC and energy-saving bulbs also defines the understanding of energy efficiency inclusions in the design.

According some of the discussants:

[.....] To the best of my knowledge indoor environmental energy sustainability, per my understanding, it involves energy efficient indoor design spaces. Energy efficiency here is key and by so doing it means that you have to optimize your energy use so there is that element of energy optimisation so you are making sure that you are not using too much energy for a giving task in design because at the end of the day, if its inefficient, it will obviously be manifested in the cost you will incur. So, with the element of sustainability just has to do with you achieving healthy indoor spaces while also ensuring the optimisation of your energy use it will go a long way of saving you cost and in so doing to as you are trying to get energy optimisation within your indoor, you also try as much as possible to maintain your air quality, the temperature within your space and of course the amount of daylighting that is coming into the space *[sic]* (FGD2)

[....] my opinion, inclusion of energy efficient technology ideas in student housing and thinking ahead in the future to use renewables in the building will help achieve sustainability. You see the nature of student housing sometimes make it difficult to recommend systems like HVAC systems in the construction because it will abuse it. So, for me, its architect in The design includes LED lighting energy saving bulbs and also check appliances used by students will ensure efficiency.

what architects can also do maybe is to make the design to have the potential of installing renewable energy systems like solar panels *[sic]* **(FGD5)**.

Moreover, it was also understood that aside energy efficiency, sustainable student housing design defines the environmental consequences emanated from the design. According to experts, student housing designers require to appreciate the four pillars of sustainability in designs. However, the major focus is usually tilted towards environmental sustainability. The following emanated from some of discussants:

[....] Because, the university environment is a social community, for me to talk about sustainable student housing design and indoor energy sustainability, I think the key perspective of sustainability nowadays is hedged on four issues. Environmental, economic, social, and institutional. The environment; whether the usage of energy is not having any detrimental effect on indoor environment of the students *[sic]* **(FGD1)**.

[...] to buttress on my colleagues understanding, the environmental aspect is key in the design, however, designer should also appreciate the social, economic, and governance aspect very well in the design. For instance, whether the usage of the energy is bringing in any detrimental effect on the social relationship among end users. The third being economical where the usage of the energy indoor also has no negative impact in terms of finances, in terms of cost associated with the properties concerned and the last which is a bit debatable is governance. Governance over here is the management aspect where indoor energy usage should be in the hands of professionals so that all these four parameters will be enhanced in sustaining indoor energy efficiency. So, designers have a lot to do when it comes to implementing sustainability in student housing *[sic]* **(FGD7)**.

Other experts are of the view that sustainable student housing is related to healthy indoor environmental condition such as air quality, thermal comfort, and visual comfort. According to expert's view, increasing ventilation systems has the capacity to solve thermal, visual, and air quality challenges which has a long run effects on not energy sustainability but student's comfort. For instance, experts shared that:

[....] Sustainable student housing design implies providing a healthy environment within the housing such that everybody including students living with disability can have access the clean energy and also optimising energy use. Thus, to say, the space must be friendly for the students by including ventilation systems *[sic]* **(FGD4)**.

[....] Picking up from colleagues, for me I think maintaining very good indoor environmental quality design such as proper ventilation, checking the humidity levels and temperatures, and

including low-emission materials in the design has impact of energy use in the housing. Maybe, ensuring passive design can check sustainable energy in the housing too *[sic]* (FGD9).

Again, the remaining experts shared different views regarding sustainable student housing designs. These experts are of the view that sustainability relates to automation, life cycle consideration, and cost-savings. The study found that automating ventilation systems and lighting is essential in sustainable student housing design. Aside, relying on indigenous building materials will serve as cost reduction during construction, and also recycling of materials will improve design performance. According to experts:

[...] So, with the issue of sustainability, I personally think that automation plays a vital role in the indoor energy sustainability of student housing and then design is also another factor we should consider. When designing, we should consider the number of windows and how to automate them. Aside, how we are going to ventilate the room, the heating ventilation and air condition system and other factors as well that needs attention *[sic]* (FGD9).

[...] Sustainable design considers the entire life cycle of building especially using indigenous materials and systems can help achieve sustainability. Also, recycling of the building materials can sustainably while minimizing environmental impact throughout the life cycle of the housing *[sic]* (FGD9).

Considering the above perceptions about sustainable student housing design, it was agreed among the discussants that sustainable student housing defines designs that support the broad sustainability pillar; environmental, social, economic, and institutional. However, practically, experts are of the view that capturing the use of sustainable materials, inclusion of ventilation, relying on natural lighting, automation, and reducing of occupancy size while minimising environmental impact and reducing cost defines sustainable student housing.

7.3 Critical requirements of sustainable student housing design

This section describes experts view on the requirements necessary for sustainable student housing in Ghana. key issues that emanated from the discussion include, gross area, indoor space circulation, window glazing, building envelop, building orientation, building automation, building

design complexity. Other non-design factors include, site selection and choice of material in the building. With respect to indoor circulation, only one expert shared his view. According to him:

[...] The whole issue about the design requirements especially in student housing is about spatial configuration. You configure the spaces such that it allows for easy indoor circulation of natural lighting and then ventilation. That's the design shouldn't be too complex to prevent natural ventilation and artificial lighting from circulating in the building *[sic]* **(FGD9)**.

[...] for me, introducing urban green infrastructure around the student housing will help reduce the effect of a larger gross floor span. Notwithstanding that, if your floor span is even small, you adopt an effective or efficient floor plan or you don't even care about how the efficient consumption of energy as far as your building is concerned, it will have a negative impact so at the end of the day, its about energy efficiency and how sustainable the design is that will help reduce this effect of a larger floor area or span *[sic]* **(FGD9)**.

Fast forward, other expert shared that the indoor circulation space also goes with the gross span of the room. For example, increasing the gross floor span will ensure energy efficiency and improve students learning in the hostels. In one expert view:

[...] At the designing stage, space is critical. We talk about volume of space and volume over here, when we talk of sustainability in the hostels, we talk of optimum space meaning optimum size and what we normally call layout needs a serious attention in the designs. This is because, the hostels are usage every day and every time which requires large layouts *[sic]* **(FGD4)**.

Other expert shared similar expression made by FGD4. However, they went further to iterate that:

[...] The larger the gross floor span of your project, it tells you that there is going to be a higher energy consumption and consequently, the carbon footprints will also be high. The carbon footprints is just the number of carbon a building will release into the atmosphere during its lifetime that is what the carbon foot print is all about and it has a corresponding connection with energy consumption. The bigger the floor span, the larger amount of energy consumption and at the end of the day, it's going to have a corresponding effect on your running cost and also negative impact on the environment *[sic]* **(FGD2)**.

[...] If you adopt an efficient design by way of a proper spatial configuration by way of energy efficient strategies to can help reduce this impact of the gross floor span of a building in our case student housing. So, it means that if your gross floor span is big, and you are able to use efficient designs by reducing over reliance of active means of ventilation and lighting while adopting passive means, it will improve your energy efficiency and also if you are able to adopt energy efficient strategies like such as efficient lighting, heating and cooling systems and also landscaping *[sic]* **(FGD5)**.

The next factor that was debatable was the inclusion of window glazing in design towards achieving sustainable student housing. According to experts, including window glazing with high shield intensity affects student energy consumption considering the tropical regions we find ourselves. Four experts expressed divergent concerns on this requirement. For example:

[...] for me it is important to consider the nature and type of window in the designs as critical requirements. Now you would realize that due to so called modernity, we are in a hot zone but some student housing and even some residential buildings are going in for glaze windows and sacrificing aesthetics for health. So, if you are going for glazed windows, you need integrate AC in the design but must use AC that does not consume so much power that will ultimately affect the cost you will incur as far as power and payments are concerned. Also, it would be good to integrate space automation to help control Air Conditioner *[sic]* (FGD8).

[...] I also see window glazing as important indicator. When we talk about window glazing as far as student housing is concerned, it is a critical factor to consider. Energy efficiency, indoor comfort, security and aesthetics. Again, as far as energy consumption is concerned, we can look at glazing at the point of emissivity of the glass that's the point of emission of the glass. It will be good to go for glass of low emissivity to reduce heat gain. For example, when it comes to the hot seasons if you just use any normal glass that absorbs and transmits heat, you will realize that your indoor spaces wouldn't be comfortable *[sic]* (FGD1).

According to FGD6:

[...] It is advisable to use low emissivity glass such that during the hot seasons or higher temperature, you glass is able to provide adequate insulation against heat. During a very cold weather like during harmattan over here we also have the use of glass that is double or triple layered. In some jurisdictions, they say double or triple pinned glass that will help minimize heat loss during very cold periods of the year. So, with that one, it is advisable to use the double or triple layered glass. It means during cold seasons; it will reduce the energy you will use to heat up your spaces. In our case, when it comes to very warm seasons, it means when you are using a low emissivity glass, it will reduce the energy consumption as far as your space cooling is concerned in the student housing *[sic]* (FGD6).

Away from the effects of window glazing on energy consumption, another discussant expressed that window glazing integration can serve as security and aesthetics to student housing investors.

In expression:

[...] In my view the glazing is a very good requirement. But I will look at it at the angel of security and beauty. For instance, in terms of security, we have this tinted glass that can withstand impact from external items. For aesthetics, a s we all know, glass has a very good appeal. It's another way to market the student housing to attract more prospective student occupants into your building. Glass also helps us to achieve good views depending on the view you want to achieve with your building, glass provides a very good view *[sic]* (FGD7).

Moreover, experts shared another view that building orientation forms one of the critical requirements in sustainable student housing design. According to experts, orientation such as the position of the building, window direction, access to greenery, and shading have impacts on energy sustainability. During the discussion they shared the view in this way:

[...] When it comes to the orientation of the building, I realized that if you have a proper orientation of the building, there is no need for you to use a lot of energy. I own a hostel with someone, and what I have realized all these years, the first two buildings, the orientation is different from the second one. Because when they built the first one, they realized that whenever it rains, and whenever there is sunshine, it directly affects them. So now the second one, they had to change the orientation of the building so I think all these things should be requirements and importance we need to take into consideration *[sic]* **(FGD4)**.

Other experts are of the view that:

[...] For building orientation, is just about how a building is positioned where its facades or elevations are facing. That one has a lot of goals. When you orient the hostel whether let's say you want to get less ventilation or less solar heat gain, and shading. If you orient it such that it directly faces the sun, of course you will get the excessive heat gain and of course the day lighting will be achieved. You orient it such that your windows are facing where there is enough day light coming in. For universities like Cape Coast, student housing investors can orient the buildings to harness breezes that is in terms of ventilation all these are ways to make the hostel energy efficient. *[sic]* **(FGD3)**.

In FGD1 view:

[...] including building orientation ideas in the design is very important. Building orientations are also critical as far as views are concerned. For instance, when they give us two views let's say one is an area of greenery and the other is just a hard landscape. I will go for the one facing the greenery. Ideally, the greenery has a mental soothing. Because it can affect students' psychology and state of mind that will help to improve the learning comfort, health and general wellbeing *[sic]* **(FGD1)**.

The last discussant shared different view that:

[...] I want to add up to my colleague's view. For me, I think orientation is also critical if you want to achieve shading. Shading at the end of the day also reduces heat gain whether you are embedding the shading device into the building by way of how you are even configuring the design, rather than coming to mount a shading device unto the structure. So, by way of building orientation, this is what I can discuss *[sic]* **(FGD5)**.

Additionally, the discussion revealed that material usage forms a critical contribution towards energy sustainability in student housing aside, the orientation, envelop, indoor circulation, design,

and gross floor span. Experts are of the view that one critical material is the choice of cabling and wiring design. According to one expert:

[...] think with the design being the basis of this, I am considering material factors that may affect student energy consumption levels is the cables used in the building. At the initial design of student housing the accessibility of cables and the ventilations into the building and also the safety requirements that will be put into the building later on should be considered *[sic]* (FGD7).

[...] also support my colleague's view. Look! there is one thing that I don't know if it's an issue here and it's about wiring of the whole student housing because there are types of cables used in your wiring, if they are small or you realize that you use a lot of energy. So, I think all these things should be factored in when it comes to student housing design and implementation because students use a lot of energy so if you are not using proper cables in your wiring then that is an issue. The effects are normally seen with burnt of sockets *[sic]* (FGD5).

Lastly, experts shared that including automation in designs needs to be integrated into the design. According the discussion, it was evident, automation of lighting in student housing were able to collate the daily number of use space and measure carbon footprint, check the levels of water conservation in student housing. In an expert view:

[...] I am going to stress on automation. I think one thing we are lacking here is building automation. Integrating IoT devices into our student housing to automate them in the sense that even if you are not in the hostel and you forget appliances left on, when you leave, from your phone or device, you can quickly turn off those appliances and this will go a long way by helping us consume energy efficiently *[sic]* (FGD8).

Similarly, another expert shared that:

[...] I think it rests on the type of tool or service you want to automate. Something like light, if there is no movement, power should go off. If you are using TV, if the TV cannot sense any eye, it should go off. Those things are applicable within the students' housing". And water to, as far as water consumption is concerned, using a borehole system, sometimes when the tank gets full, of course we are using power to pump the water unless someone literally walks to switch off it is kept running". There is even this tank that has been design in a way that whenever the tank is full, the power cuts. These are some of the things that needs to be automated in the designs *[sic]* (FGD2).

Another expert is of different view that:

[...] This concern of automation, looking at student housing, how feasible is that going to be. I think if it's our personal homes, that will be fine but looking at say, school hall or probably hostel with about 200 students and you are talking about automation, how is that feasible *[sic]* (FGD4).

However, one expert counteracted that:

[...] For me I do not agree with my colleague who indicated that automation is not possible in student housing design. Let me give you an example, there are student houses in university of Ghana that do no longer use key but use cards. Aside, they use automated system which can tell you the number of students living int the hall during checkouts. So, in case of fire outbreak, you can provide the number of students that were inside. So, we need to integrate these in designs *[sic]* (FGD9).

Regarding one of the non-design requirements, are of the view that controlling students' attitude towards energy use is crucial. These include; gadget and appliance monitoring, lighting and water control. And window opening behaviours. According to one expert:

[...] For me I think that after implementing all what have been said and don't look at the user side, we are making a mistake. We need to ensure that students have responsible energy-saving behaviours through education and engagement *[sic]* (FGD3).

Considering the discussions on the requirements of sustainable student housing, experts were asked to rank all these findings. Unanimously, experts shared that building orientation and building envelop are the first requirements that needs to be considered. The second aspect was concerned with window glazing, indoor circulation space, and gross floor volume, the third aspect was to deal with automation, and students' behaviours. Finally, material usage was ranked last.

7.4 Barriers of sustainable student housing design: experts view

This section describes experts' views on the barriers of sustainable student housing design. Experts are of the view that student housing investors do not have much knowledge especially when it comes to using renewable energy sources. Others expressed that investors see sustainable student housing as expensive and take much time to recoup the investment. Aside, resistance to change has been another barrier. Moreover, there appeared to inadequate research in sustainable student housing affects its adaptation. According to one expert:

[...] I think the long run benefits of sustainability is a huge barrier. If you start sustainable now, you will start reaping its benefits in five-nine years' time to come so investors feel reluctant to invest in sustainability. They want immediate returns. I would say all rational investors are risk averse so the long run benefit of the nature of sustainability is a major barrier *[sic]* (FGD8).

Another group of experts opined that:

[...] My point will be on financial risks. There may be concerns about whether the returns on an investment from sustainable practices will be materialised in a reasonable time so that deters investors to initiate sustainable development plans in student housing *[sic]* **(FGD6)**.

[...] the barriers all drawn down to cost of materials. Student housing investors' main motive is to maximize profit so when they look at the investment they are going to put in and the time it is going to take them to recoup the benefit from this investment that they make, they turn to draw back from investing in sustainable buildings and designs. The other point I am going stress on is regulations. Government and agencies that have been put in place to manage the affairs of building construction are not doing the work when it comes to regulating building construction. Building plans are not even properly checked before approval *[sic]* **(FGD4)**.

[...] My first point is on the cost and benefits of sustainable designs. These investors are also thinking of profit. When are they going to get the profits. So, I think the cost involved and the benefits. The duration of reaping your benefits is a barrier to investors *[sic]* **(FGD1)**.

Regarding the level of awareness, experts' opinion on showed that there is low level of knowledge on sustainable student housing in Ghana. According to one expert:

[...] Knowledge about sustainability from the perspective of end users and producers; A lot of people don't even know about the benefits of sustainability and sustainability as a project, is capital intensive the initial outlay is big although it doesn't take one person to initiate it. It should be a group and getting a group to invest in one thing is another hindrance. Another benefit that is not obvious is social integration and not being obvious serves as zero to end users or investors so it not being obvious serves as an obstacle that will hinder the adoption of sustainability *[sic]* **(FGD5)**.

[...] The lack of education on sustainability issues. Most of our investors even though knowledgeable and having the money, they don't have the idea when it comes to these things so there is not enough knowledge on sustainability designs or sustainability issues. So, you see when there is no knowledge, you are only thinking of the money you are supposed to get back and it affects your decision making. There is one other thing that has to do with expertise. Incorporating sustainable designs such as automating, when there are issues, how do we solve it, they have to come from elsewhere. Even putting on Zinc roofing, you have to bring them from elsewhere so there is that gap as well where people have to look for expertise and these people are also difficult to get so they result to using something simple. These are kind of barriers to it *[sic]* **(FGD4)**.

Also, the lack of research and fear of changing from conventional student housing model to a more sustainable one is challenge. According to expert discussion:

[...] Something that has occurred to me as a major hindrance is the fear for change, resistance to change. Sustainability in terms of facilities or buildings I will deem it as innovation. Innovation is a sharp change in whatever we do. The fear or resistance to change also serves as another social hindrance in the adoption of sustainability designs *[sic]* **(FGD3)**.

Another expert shared that:

[....] Don't you also think that inadequate research also plays a role? When it comes to the adoption of sustainability in student housing, research is key for instance let me put the environment. The environment or climatic nature of this place is different from the global North. Now we want to adopt solar we can do it here. What about the other zones. So, for me I think there should be enough research into these areas to encourage investors in student housing. We only see few residential houses in Ghana using them *[sic]* (FGD9).

7.5 Summary of focus group discussion

The purpose of this section was present the understanding of energy experts' viewpoint on issues of sustainable student housing requirements and barriers of sustainable student housing design in Ghana. Expert shared divergent views, which includes issues of building orientation, building envelop, indoor circulation design, window design and glazing, automation, and student energy management as some of the critical factors in sustainable student housing design. However, experts were of the view that financial, knowledge, social, environmental, and lack of research were the key barriers of sustainable student housing design in Ghana. At large, most of the experts had enough knowledge on sustainable student housing design.

CHAPTER EIGHT

DISCUSSIONS OF RESEARCH FINDINGS

8.1 Discussion of descriptive results

This section discusses the descriptive results of respondent, model 1 and 2 of objective 1 and objective 4, and EFAs of objective 2 and 3. The descriptive results showed high participation of male respondent than females, which align with studies (Appau et al., 2024; Simpeh et al., 2021). However, this imbalance did not have impact on the studies. The assessment of the models is to essentially understand the correlation between the theory adopted and the data collected. Assessing the reliability coefficient of these models using the reliability Cronbach's alpha criterion and R^2 reliability approach, the study models recorded high values (0.90) which is classified as good and acceptable (Hair et al, 2016). All factor loadings were very high and extracted except BDLH4 (0.697) in model 1 which did not meet the threshold in the pre-model run. This is in line with Gefen and Straub (2005) who supports the removal and re-run of constructs that do not meet the minimum required threshold. In terms of establishing the direct and indirect relationship, only model 2 met the criteria.

According to Hair et al. (2019) the assessment of both direct and indirect models should have more than one latent variable and observed. However, testing the relationship between the variables shows that model 1 recorded positive relationship between the student housing requirements on heating and cooling than model 3 which reported one insignificant variable of building use factors that explains student behavioral factors and energy consumption. Further, the model showed large effects size (above 0.350) that defines the contributions of each construct on heating and cooling, and energy consumption in student housing (Chin, 1998; Gefen et al., 2000).

Moreover, EFA results in objective 2 and 3 showed that all factor loadings were above 0.5 threshold as supported by (Attakora-Amaniampong et al., 2020). Data suitability test in both models shows high significant and acceptable values (Obj2=0.827 and Obj3=0.789) as compared to KMO (0.516) as seen in Attakora-Amaniampong et al (2021). Among the two models, there were not multicollinearity issues.

8.2 Critical drivers of sustainable student housing requirements in Ghana

The study assessed the drivers of sustainable student housing design requirements in Ghana based on building envelop, building orientation, indoor circulation space, building design and geometry, design complexity and shape, building height and storey levels, window glazing and efficiency, and gross indoor area span. However, assessing these requirements based on energy experts view and quantitative findings revealed that indoor circulation space, gross indoor span area, window design and glazing efficiency, and design complexity and shape were critical student housing design requirements considered in designs dissimilar to studies (Gupta and Deb, 2023; Liu and Wang, 2022; and Homod et al., 2021) who found the others drivers as critical. Interestingly, most of these studies are found in Asia, Europe, and Gulf regions. This could also be that most of these studies are conducted in areas with high storey heights compared to the case of Ghana.

Further, this study assessed the impact of these drivers on heating and cooling in student housing. Based on the PLS-SEM model, the study found good internal reliability, goodness-of-fit, discriminant validity, convergent validity, and good effects sizes which largely explains the effects of design requirements on heating and cooling, as supported by (Hair et al, 2019). Overall, the hypothesis testing revealed that these requirements had a positive relationship with heating and cooling systems as supported by Mostafavi et al. (2021). The study further found that building envelops contributed about 102.0% effects on heating and cooling in student housing which looks

higher than Liu and Wang (2022) study who found that optimization of the building envelop leads to a reduction of annual energy loads of about 47%, but suggest a consequential effect on comfort as indicated by the integrated design theory. According to Maaouane et al. (2023), further optimising the building envelop lower energy consumption by 31%–56%. However, drivers of building envelopes showed positive significance towards heating and cooling in this study. For instance, unlike Mostafavi et al. (2021) who found that enhancing building envelope reduces energy consumption by 78.9%, this study recorded high explanation power of 90.0% of glazing requirements compared to the nature of façade material (80.8%). The contributions of building mass requirements of building envelop showed highest effects on heating and cooling by 90.8% compared with nature of façade material and glazing requirements. Technically, this requirement supports Homod et al (2021) as critical building envelop requirements, but have lower contributions (47.8%) on energy saving potentials in Iraq.

Moreover, requirements related to building orientation showed 34.2% effects on heating and cooling in student housing, which confirms experts' views as the fourth most relevant requirements in sustainable student housing design. According to the study, drivers related to sun direction and view contributed about 82.6% that defines the level of consideration of building orientation in student housing designs. In effects, Cui et al (2020) confirms that this led to high risk of pollutant exposure at the leeward view of the residential building than the windward side. On the other hand, this study saw that shielding from external noise was the least factor that contributed to building orientation requirements considerations in student housing. This is in line with Yang and Jeon (2020). Building orientation requirements related to privacy showed positive significance in defining the building orientation requirements in sustainable student housing design in Ghana.

This is a new direction that defines the purpose of building orientation considerations compared to view, wind direction, shielding from external noise as seen in literature.

Aside building orientation, indoor circulation and design requirements recorded negative (-44.9%) effects on heating and cooling. According to Ozarisooy and Altan (2022), indoor circulation design has a significant and strong correlation with heating consumption patterns than cooling in South-Eastern Europe. Similarly, Alghamdi et al. (2022) is of the view that indoor circulation systems related to cooling set-point temperatures significantly reduce the indoor temperature by 20.0% which reduced energy consumption by 41.0% among education building in Australia. Following the negative contributions of indoor circulation design and the less reliance of this indicator in the focus group discussion, this suggest that student housing designers do not consider indoor circulation space as critical to heating and cooling in Ghana. The ripple effects could be high energy consumption exacerbating from heating and cooling systems in student housing. Evidence related to indoor circulation were largely centred on the efficiency of circulation route in the building, which is in line with Hou et al. (2022) who observed that most university buildings in China shown indoor air change rates as main factors affecting the cooling and heating load compared.

Contributions of logical flow within rooms recorded factor loadings lower than the threshold reported by Hair et al. (2019). This is not in line with similar study in United State who found that that logical flow within rectangular-south-oriented classrooms showed minimal energy use compared to rectangular-north-oriented classrooms (Alkhatatbeh et al., 2023). Others such as the consideration of common areas and space and circulation space in building orientation requirements were positive. Similar integration in Li et al. (2022) among university dormitories in China, found high temperature values for living room and master bedroom, window-to-wall ratios

for the bedrooms than the other remaining rooms. Aside, evidence of 72.8% contribution of circulation space in building orientation in this study is not different from cases observed in Uddin et al. (2022) who found that the adjustment of interior designs improves energy performance by 14.9%, and Al-Yasiri and Szabó (2022) who found that at increase in natural night ventilation by 28.6% compared to temperature during the day in hot summer in Iraqi.

Window design level and glazing forms the second negative requirements that defines student housing design requirements in Ghana. This contributed about -58.3% on heating and cooling in student housing in Ghana. Contrary, Cherier et al. (2024) is of the view that widow design level and glazing recorded high effects than window size and orientation on energy savings by 6.92 % for a hot semi-arid climate building and maximum of 9.8 % in a cold semi-arid area in Algeria, which is dissimilar to Ghana. Among the drivers of window design levels and glazing, this study recorded that ventilation and acoustic performance, sun shading and geometry, efficiency of window glazing, and shape of window glazing showed positive significant. Even though the construct defining these variables shows negative, evidence in other studies showed high relevance in residential design. For instance, De Luca et al. (2022) showed that static shadings glazing reduced visual discomfort by 89% and energy use by 29.1% with adequate levels of daylight. Mahdavinejad et al. (2024) on the other hand also found that using a self-shading glazing design increase the quality of view by 75% while increasing energy saving.

Liu et al. (2023) found that using the optimized photovoltaic shading devices in lighting and cooling and reduced by up to 48.7%. For positive contributions of ventilation and acoustic performance requirement on heating and cooling, Mohammed et al. (2022) found that sun shading of horizontal fins contributes about 5% reduction in the cooling load of the building. Conversely, the overhangs of shading devices recorded about 9.2% energy savings. Instances related to acoustic

contributions of the environment significantly contributed to determining window usage (Torresin et al., 2024). On another positive side, Dabaj (2022) have proven that the efficiency of window glazing has a correlation with shape of window glazing as evident in this study. Its contributions to heating and cooling are determined by quality of view, useful daylighting in the building, daylight illuminance, and the daylight glare. Contrary to the negative contribution of this indicator, Gamalia et al. (2023) witnessed that the efficiency based on top-hung type of window openings in an elementary school produced airflow and noise levels that does not meet the Indoor Environmental Quality (IEQ) requirements. This could be a gap that is similar to results found in this construct.

Indoor floor span is one of the factors that accounted for negative effects on heating and cooling in the study. According to González-Torres et al. (2022), building floorspace and number of building unit should be considered in analysing energy statistics. While, architect did not consider this as critical to heating and cooling demand in student housing, Chen et al. (2020) is of the view that optimizing the size and shape of the building can reduce the level of energy demand in the building. The over -115.8% contributions of indoor floor span in student housing design are not surprising as Al-Saggaf et al. (2020) also found similar results. According Al-Saggaf et al. (2020) window glazing, complexity of shape, and building orientation designs characteristics had a high effect on cooling loads demand in the buildings as compared to indoor floor area in hot climatic region. Considering this indicator, vast literature has silently used it in energy studies. However, the reasons for its negligence have not been studied. While, Appau et al. (2024) study in Ghana confirms that the high occupancy in student housing affect energy use intensity, it is possible to understand the correlation between indoor floor size and number of students living per room affects

energy demand. This establishes the case for further investigations into the high negative effects of indoor floor span on heating and cooling in student housing in Ghana.

Another interesting finding that answers the question on the critical design requirement and effects on heating and cooling in student housing was building design levels and height. According to Architects, this contribute about 112.2% which is largely above 100%. This gives a strong indication of consideration in student housing design. This aligns with Park et al. (2021) and Aboelata (2021). All the drivers the defines building design levels and height showed very strong support except the requirement that focuses on vertical movement in the building. This was rejected because pre-bootstrapping analysis reported values less than 0.70. Values related to building height consideration in student housing was positive and supported in Park et al. (2021) study in South Korea who found that flat-type apartments recorded reduced energy between 20 °C and 26 °C towards the southward orientation a westward orientation compared to the tower-type buildings. Similarly, this result supports Cao et al. (2021) who found a correlation between air temperatures and building heights in Beijin. Away from its contribution to heating and cooling, Mangan et al. (2021) also reported high significant ratio for building height than orientation in the energy and cost performance of square pavilion and rectangular buildings. Within the African context, Aboelata (2021) shared different view.

According Aboelata (2021), introducing green roofs can only achieve the maximum reduction in cooling energy by 1.3–3.2% for buildings with 30m height and 13.3% in buildings with 12m height in Cairo. Despite, the limited consideration of indoor floor span requirements in this study, considerations for building functionality and use were key requirement that defines the building levels and height in student housing. To confirm this, Jung and Jazizadeh (2020) demonstrated that personal thermal comfort was high compared to the number of occupants that share a thermal zone.

Aside building density, six occupants observed average energy efficiency gain of 21.4% when assessing building design effects on energy saving based on multi-occupancy scenarios in climatic zones.

8.3 Drivers of sustainable student housing in Ghana

The study assessed the drivers of sustainable student housing designs using Exploratory Factor Analysis. Exploratory Factor Analysis results showed strong and high values of internal data reliability test and test of data sphericity above values recorded in Attakora-Amaniampong et al. (2023). The results showed extracted factors such as financial, health and comfort, economic, building designs, and environmental drivers of sustainable student housing design which is different from large studies related to green buildings, green financing, and green construction in residential and office buildings (Agbajor & Mewomo, 2024; Debrah et al., 2023; Hussain et al., 2023). However, key indicators did not record critical environmental indicators that defined the factor, which implies that none of the indicators were relevant in environmental decisions. On the other hand, market drivers, knowledge-related drivers, all-inclusiveness and social drivers, and institutional policy drivers did not determine student housing investors decision in sustainable student housing designs. Based on this, financial, economic, building design, and health and comfort drivers were discussed.

8.3.1 Financial drivers

Financial drivers are classified as on the determinants of sustainable building decisions. According to the results, financial drivers were ranked as the highest (0.823) among other drivers of sustainable student housing designs in Ghana. this driver was largely influenced by high energy cost (FD1) to student housing investors and the energy sharing mechanism to students (FD2) has a high explanation power than desired space for students, student housing life cycle cost, and

reduction in construction cost. Comparing these indicators, high energy cost showed factor loadings (0.503) which is less than Oke et al. (2024) who recorded factor loadings (0.812) of cost of energy saving as critical financial related drivers of sustainable construction in Nigeria. The potential reasons of the cost of energy were attributed to the fact that students use high energy consumption gadgets. This in line with Appau et al (2024) and Zhang et al. (2024) who found that improper insulation, and underregulated use of heating, ventilation, and air-conditioning systems increase energy bills in student housing. on the other hand, while energy sharing mechanism challenges continue to affects energy use in student housing, it served as the second most critical financial determinant influencing the adaptation of sustainable student housing design in Ghana. Considering the high consideration of energy sharing mechanism, it is very important to understand the models and its consequential contributions to energy consumption in the Ghanaian student housing market. Evidence from other studies (Zhou and Lund, 2023; and McCord et al., 2024) show that the fairness allocation and distribution of energy cost-benefit had mutual, economic benefit, and improve energy efficiency in smart cities in Europe and China.

Moreover, it was interesting to understand that life cycle cost did not show any financial reasons for adopting sustainable student housing design in Ghana. Despite less reliance of this indicator in student housing studies, Gulcimen et al. (2023) study sustainability assessment in university campuses using life cycle method found that 80% of energy cost constituted the total life cycle cost \$200/person in university campuses. Similarly, Tsantili et al. (2023) also assessed the life cycle cost of university buildings related to maximum energy performance in Europe. The results found that the utilization of a high-efficiency chiller and gas boiler resulted in a decrease of 12.67% LCC in Mariloca and reduction in energy cost of 17.6% in Palermo. Considering the geographical orientation of these studies, it was not surprising to see its insignificance as a financial driver in

determining the adaptation of student housing designs in Ghana. Other financial drivers such as reduction in cost of construction and energy, and the high commercial viability of sustainable student designs did not show any contributions which contradicts student housing studies Bungau et al. (2023) in Romania, and Abdollahzadeh et al. (2023) in Iran.

8.3.2 Health, safety, and comfort drivers

Studies related to health, safety, and comfort have shown some relevance factors that influence the adaptation of sustainable buildings. However, most of these studies related this factor to green buildings and sustainable constructions. In this study, health, safety, and comfort drivers recorded the highest determinants of sustainable student housing designs. This result looks similar to Ebekozen et al. (2024) who found that health and occupant comfort were ranked among the highest 18 items that drives sustainable housing in Africa, and Wang et al. (2024) also found a low energy consumption hotspot, improved indoor environments, and facilitate better health for occupants when adopting green buildings in Europe. Factors related to health, safety, and comfort have largely been associated to thermal, visual, and acoustics in literature (Appau et al., 2024; de la Hoz-Torres et al., 2024; Abdollahzadeh et al., 2023). However, this contradicts with de la Hoz-Torres et al. (2024) who investigated indoor thermal comfort school building in Oman and found the satisfaction for indoor air quality than acoustic, thermal, and visual comfort, and Abdollahzadeh et al. (2023) who also used computational simulations to assess indoor environmental quality in student dormitories and found thermal and acoustic insulations as high effects on energy compared to acoustics and visual comfort.

On the contrary, it was surprising to note that student housing investors did not consider comfortable indoor health as critical to adopting sustainable student housing designs in Ghana. This result is not in line with other studies in offices, hospitals, and other residential building types

in the global north, for instance, Roumi et al (2023) who reported that to achieve high occupant satisfaction and comfortable indoor environment, visual comfort and outdoor view required priority of improvement; Nimlyat et al. (2024) who found that hospital design configuration and ward orientation are the most challenging aspect of hospital designs which affected patients' indoor health outcomes; and Oh et al. (2023) who also found that indoor environmental quality influences working environment and enhance occupants' indoor behaviours. Moreover, it is important to understand that the lack of consideration of the indicator 'comfortable indoor health' as a relevant health and comfort driver towards adopting sustainable student housing designs could be attributed to the lack of understanding of what constitute the potential benefit of sustainable student housing designs or could be other related market conditions which was not explained. The ripple effects of the challenges of existing student housing conditions have been iterated by Jia et al (2021) as exhibiting bacterial and fungal aerosol pollutants which require the optimization of passive designs to control thermal comfort. Also, the safety aspects of adopting sustainable student housing have been proven to be beneficial in Liu et al. (2022) when assessing the future considerations of green buildings. Even though this study falls outside the scope of sustainable design in student housing, investors in student housing in Ghana did not see it as critical health drivers in investment decisions.

8.3.3 Economic drivers

Economic driver forms one of the major drivers of sustainable building in other studies. According to this study, economic driver is the third highest driver of sustainable student housing designs in Ghana. This aligns with Zhang and He (2021) who found economic drivers as third driver aside social, technical, and policy drivers when assessing the drivers of green roof implementation. Aside, the study conforms with Tokbolat et al. (2020) who found that out of 5 drivers, economic

drivers were ranked as moderate compared to social, financial, and environmental. Related to the indicators that drives the economic drivers, climate change served as the highest factor compared to affordability of building design, the emergence of active and passive design e.g. use of air conditioner, building energy efficiency, and reduction in waste and water efficiency. This conforms with Assylbekov et al. (2021) study who found economic drivers such as energy efficiency, environmental impact, operation cost, and climate change to influence sustainable buildings in Kazakhstan. However, this result deviates from Mushtaha et al. (2021) who found climate change as the second most important economic driver which influences sustainable building investment compared to legislation, customers behaviour, finance, target market, investors preferences, organizational culture, and energy efficiency.

8.3.4 Building design drivers

Building designs requires great attention in student housing. However, the evolving student housing design in Ghana do not meet the essential requirements of sustainable buildings, ineffective implementation of designs, leading to high energy use intensity (Appau et al., 2024). In this study, building design drivers was ranked as the 3rd. according to the study building layout for student movements, aesthetics, desired space for studying, flexibility in the use of stairs and all-inclusiveness were indicators assessed. Key determinant criterion for aesthetics and the desired space indicators explained 48.5% and 32.9% which is very low but supports Keser Aschenberger et al. (2023) and Seifhashemi and Elkadi (2022) who study found aesthetics and the desire space for studying are key in sustainable building designs. However, the study found a negative variable explain which implies student housing investors negative perception of flexibility in stairs in sustainable student housing design. This is a strange result considering the challenges of stairs

usage and its cleanliness affecting student living with disability as observed in Appau et al (2023). Anyway, this could be among the other drivers that do not necessarily influence decisions.

8.4 Barriers of sustainable student housing design in Ghana

The study assessed the barriers of sustainable student housing design in Ghana. situating the barriers into: knowledge-related, social, regulatory, economic, financial, and environmental-related barriers, economic-related barriers recorded the lowest contributions to factors affecting the adaptation of sustainable student housing designs in Ghana. unlike the drivers, the results in this chapter aligns with limited studies related to green building, green construction, and green financing in global south. Similarly, to the drivers of sustainable student housing design, environmental indicators though high, did not record values explained in this chapter which is supported by Addy et al. (2021) who found that environmental challenges are not immediate concerns of adopting sustainable buildings in developing countries, especially in SSA countries compared to economic, regulatory, finance, knowledge, technical, and social barriers. Based on this, the discussions would be centered on social, knowledge, regulatory, and financial barriers.

8.4.1 Social barriers

Social related barriers were ranked as the critical barrier affecting student housing investors decisions to adopt to sustainable student housing design. This result supports Tokbolat et al. (202) study who found that social barriers affect the level of sustainability in using efficient construction materials. Aside, this result confirms Dalirazar and Sabzi (2023) who found social and economic barrier as high compared to finance and knowledge related barriers. Considering these few studies, other studies within the context of green buildings and sustainable construction do not support this finding. For instance, Kinebera et al. (2023) found that social barriers as the least barrier compared to legacy, connectivity, security, and data uncertainty when assessing 45 barriers of sustainable

twin building. Oke et al. (2023) on the other hand found that economic, and communication barriers as critical than social barriers as critical barriers.

Considering the social-related barriers, complexity of sustainable designs (SB1=0.595), long product lifecycles (buildings and materials) (SB2=0.762), technical challenges and material recovery (SB3=0.517), lack of standardization of sustainable student housing designs (SB4=0.674), and lack of student housing market demand (SB6=-0.403) is aligns with Munaro et al. (2020) who found that challenges of reuse of building products after material lifespan affects sustainability. Aside, the lack of product recovery and complex building design affects sustainability strategies. However, the high observation of long product lifecycle and lack of standardization of sustainable student housing designs has a high impact on its adaptation in the Ghanaian student housing market. In support, evidence in studies in the global north have shown some positives of sustainable buildings related to lifecycle assessment. Tokede et al (2022) is of the view that about 85% of major building life cycle impacts were more social in Australia which contributed to over \$ 3 million. Similar, Apostolopoulos et al. (2023) observed that the upgrade in thermal systems and deep retrofitting of the building envelope drastically reduce the socio-environmental effects on buildings and carbon dioxide emissions by 95 % operational lifespan of 25 years.

In furtherance of the discussion, the optimizing complex sustainable design have positive effects on improved natural lighting, improved thermal load, and improvement in usable space (Jalali et al., 2022). However, threats on the complexity of sustainable designs in other studies was supported by this study, but not highly significant indicator. Reference to Zhong et al (2022) shown that the complexities of sustainable biophilic designs have a rebound effect associated to biodiversity, health and wellbeing, and productivity. Similarly, Zhang et al. (2021) underscores

that the complexities of sustainable buildings have challenges related to realizing optimum heat recovery, and maintaining indoor thermal comfort, while achieving stable and durable building performance.

Moreover, the negative factor loadings for market indicators shows that it is not a barrier influencing sustainable student housing design which supports Ayakwa et al (2022) who found the lack of market demand as the 13 ranked challenge in sustainable building construction processes in Ghana.

8.4.2 Knowledge-related barrier

In order to adopt to sustainable buildings, knowledge level of implementer and users are critical to its adaptation. Compared to financial, regulatory, social, environmental, and economic barriers, knowledge related barriers were ranked as second. This do not support Misopoulos et al. (2023) who found knowledge related challenges as major barrier that affect sustainable best practices in UKs construction industry, and Datta et al. (2023) who also found that the lack of experts as major barrier to implementation sustainable construction projects using Building Information Modelling (BIM).

Aside, this results also Fitriani and Ajayi (2023) who found the lack of knowledge and standards as higher compared to financial constraints, and poor building design practices when assessing the barriers of sustainable building contrition in Indonesia. On the flipside, this result supports Carlander and Thollander (2023) who found risk, lack of finance, and inertia as high compared to the lack of knowledge and fear among implementers when evaluating the barriers of adopting energy efficient building construction in Swedin. This comparison looks interesting considering the geographical contexts. However, the indicators explain the knowledge considerations may show some dichotomy in these discussions. For instance, the factors extractions related to

inadequate appropriate skills for managing sustainable student housing design (eg. communication, awareness, experience, negotiation, leadership, and lateral thinking) (KB2=0.731), Lack of knowledge on profitability and cost of indoor sustainable student housing (KB1=0.741), Knowledge about building lifecycle-efficient energy solutions and running cost (KB3=0.754), lack of knowledge on environmental effects (KB3=0.612) were critical indicators related to knowledge constraints of sustainable student housing designs in Ghana. Consistent with other studies there is divergent support of these findings related to the cost and profitability of sustainable student housing designs. For example, Omopariola et al., 2024 conducted similar study and found that the cost delays and resistance to use was high compared to lack of incentives, government regulations, and techno-economic, and unwillingness of stakeholders to incorporate sustainable building materials.

Aside, Rabea'Hadi et al. (2023) found that consumers were aware that green buildings provide improved client retentions, access to emerging markets, and decreased operating expense. However, the studies found knowledge gaps related to initial cost of investing in green buildings. Nguyen et. al. (2023) also supports this finding by indicating that financial risk associated to the feasibility phase and initial investments of green buildings projects were knowledge gaps. Moreover, knowledge gap associated with high costs involved in the green building retrofitting process and cost of maintenance affect green retrofitting of existing residential buildings in South Africa was evident in Amoah and Smith (2024), supports this finding. However, these studies are largely related to green buildings. A close study that supports this finding was evident in Hu (2024) who found the lack of cost estimation transparency as critical knowledge barriers facing sustainable affordable building design. This is a good indicator that could affect sustainable student housing design implementation in Ghana.

Moreover, the levels of concerns related to inadequate appropriate skills for managing sustainable student housing design is valid evidence in other studies. For instance, Dadzoe et al. (2024) found that stakeholders developed positive attitude towards the adoption of green construction through research studies. However, the studies found that majority of stakeholders did not have skills and experience in green building construction in Ghana. Related to residence knowledge on green technology usage in building development shows that there is about 82% of homeowners who have different knowledge about green technologies in residential buildings in Ghana (Simpeh et al., 2024). These studies, even though not related to student housing provide supportive evidence that the levels of investors and users of sustainable buildings do not have knowledge and skills about its development. This may have a serious risk when implementing sustainable student housing designs in Ghana. Notwithstanding, lack of environmental awareness as a knowledge gap in this study is supported by Jaradat et al. (2024) who found the lack of public awareness of the positive environmental impacts of adopting sustainable buildings as critical

8.4.3 Financial barrier

Financial barriers form the third critical challenges of sustainable building adaptation in both developed and developing countries. Considering the critical component of cost and paypack returns of adopting sustainable buildings, the adaptation of sustainable buildings has become a topical challenge in other studies. In this study, financial barriers were ranked as the 4th barrier influencing sustainable student housing design in Ghana. This implies that financial barrier does not largely constitute a constraint among student housing investors in Ghana. Furthering these results with the context of other related studies, it was observed that most supported findings were related the purchase of green renewables, sustainable building implementations, and the use of sustainable building technologies. For instance, Akcay (2023) found cost and demand barriers as

main barriers compared to government, time, people-related, and market barriers of green building adaptation in Turkey.

Similarly, Akinsulire et al. (2024) on other hand found that financial barriers related to initial cost of sustainable building materials was higher than barriers related to awareness, technical expertise, and regulatory challenges. On the contrary, studies (Al Mamun et al., 2023, and Gounder et al., 2023) recorded lower rankings for financial barriers which supports this study. This study established four critical barriers of sustainable student housing design to include: high building material prices (FB2=0.688), high upfront investment costs in purchase of sustainable building materials (FB1=0.843), limited funding (FB3=-0.451), and long payback period and investment risks (FB4=0.873). All these supports findings in (Akçay, 2023; Gounder et al., 2023). However, the low level of funding in this study shows the lack of concern as a barrier to sustainable student housing designs. This coupled with the lack of incentive provision by the government of Ghana, it supports the fact that student housing investors do not rely on any funding to put up sustainable student housing.

8.4.4 Regulatory barriers

According to the study regulatory barrier form the last barrier that influence sustainable student housing designs in Ghana. Situating these results within the context of other related studies, few numbers of studies rank regulatory barriers as second order barriers. For instance, Ogunsanya et al. (2022) assessed nineteen variers to determine the barriers of sustainable construction in Nigeria using exploratory factor analysis. The study found that national policy regulations as second to last barriers compared to knowledge level, governance, construction industry challenges, and mismatch in procurement processes as barriers. Wang et al. (2023) on the other hand identified barriers of using prefabricated buildings in China. Technical barriers were high compared to

economic, political, society, and management regulation barriers to enhance prefabricated buildings in China. Away from these commonalities, many studies have highlighted regulatory barriers as major barriers in sustainable buildings.

Evidence in Babalola and Harinarain (2024) when assessing the policy barriers of sustainable construction practices in Nigeria using factor analysis found that regulatory barriers as major barrier compared to challenges of implementation, owners' input, stakeholders' policy, and government policy barriers as critical. Aside this reflection, Ohene et al. (2022) observed the lack of regulations as higher compared to implementation and economic barriers such as uncertain long-term payback period when evaluating the barriers of developing strategies towards net-zero carbon buildings. Another recent study (Zulu et al., 2023) in Africa also found regulatory and level of awareness and knowledge barriers as higher compared to economic, and financial barriers when examining the barriers of sustainable construction in Zambia using relative important index (RII). Despite the increasing trend of studies within the context of green buildings and sustainable construction in the global north and few cases in the global south, this result shows little variations of regulatory barriers as the main barrier to sustainable student housing designs in Ghana.

Argument on the critical regulatory barriers have been levelled against the lack of consistent regulatory framework, obstruction laws and regulations, level of regulations, and lack of institutional framework on energy auditing. According to this study the lack of consistent regulatory framework ($RB1=-0.398$) and obstructing laws and regulations ($RB2=-0.490$), showed negative values which implies there is no challenge with laws regulating sustainable student housing design. However, these results do not support studies: Li et al. (2021) who found that inconsistencies in green building policies towards tax incentives, relevance of policy agenda, and structural deficiency in information services delivery, Zepada-Gil and Natarajan (2020) who also

found out a consistent adoption of institutional regulations on innovative carbon emission in Mexico and Chile while, there was poor enforcement of regulations in Argentina. However, they further found a progress in regulations and standards with challenges in enforcement in Latin America. Similarly, in SSA countries such as Ghana, Anzagira et al. (2019) and Agyekum et al. (2022) who found the mandatory imposition of government regulations and awareness campaigns as a challenge and lack of government incentives and institutional framework for effective implementation of green buildings in Ghana.

However, the results support Obeng-Darko (2019) who found legal and regulatory problems such as lack of independence of institution structures, lack of regulatory assessment, and lack of legislative instruments as critical regulatory barriers in renewable energy in Ghana. This implies legal regulatory challenges are largely tilted towards renewable energy and green buildings and not sustainable student housing designs.

However, it was interesting to find that the lack of energy audit and assessment ($RB4=0.685$) recorded high values than lack of legal regulatory framework and obstruction of laws in the study area. This implies that student housing investors are more concerned about the energy impact of adopting sustainable student housing designs. According to Alfaoyzan and Almasri (2023) the high consumptions in the use of air conditioning system and lighting in university campuses affect sustainability. Evidence in other university housing studies have proven that some sustainable buildings in university campuses across the gulf regions and Europe have challenges with energy audit. For instance, Basu et al. (2023) found that the mismanagement of electricity regarding the use of air conditioning, lights, and sockets loads. The auditing recommended the changes of air-conditioning types from non-inventor to inventor, incorporating PV solar systems, and replacing incandescent bulbs with sensory lights and LED bulbs.

Similarly, these findings support Rey-Hernández et al. (2023) who also found that energy auditing showed 15 university building out of 19 reached the net-zero building targets, which resulted in a reduction in carbon dioxide emissions by 1.6 kgCO₂/m²·y in Valladolid, Spain. To control challenges of energy consumption in university campuses through auditing, Bui et al. (2023) is of the view that the implementation of building rating systems and financial incentives for carbon-reduction solutions is relevant.

8.5 Impact of student behaviour factors on energy consumption in student housing in Ghana

This section assesses the drivers and effects of student energy use behaviour on energy consumption in Ghana. Earlier studies have identified age, gender, indoor environmental quality condition, nature of building windows, occupancy ratio, and health related conditions in residential buildings affect energy consumption (Du & Pan, 2022; Fan et al., 2021; Deng et. al, 2021; Ortiz et al., 2020). In this study, these drivers were conceptualized into physical, psychological, physiological, social, and contextual drivers, which aligns with the attitude, subjective norms, perceived behavioural control, and behavioural intentions premises of the theory of planned behaviour. The PLS-SEM analysis showed that social drivers were the main factors that determines student housing energy use.

The analysis established that social drivers have high relationship with energy consumption, which supports the theory of planned behavior. Besides, the model reported positive significant values for indicators such as number of students in rooms, social and personal influence, window openings, and cloth changes. Among these the number of students in a room, sleeping hours, and studying hours contributed to the highest energy consumption in student housing. This result looks similar to few studies in residential and office buildings who considers number of occupants as

drivers of energy consumption (Reveshti et al., 2024; Akbari & Haghighat, 2021; Chen et al., 2021; Mokhtari & Jahangir, 2021). Second supporting social driver was social and personal influence among students in the university housing which is connected to the subjective norms premises of the theory of planned behaviour. This finding is not common in literature as especially related to student housing studies. Large number of studies (Sajjad et al., 2024; Baltruszewicz, et al., 2023; Askarizad & Safari, 2020) situate this variable as a determinant of behavioural factors but do not assess its efficacy in assessing both direct and indirect effects on energy consumption. At best it classified as a mediating factor of social norm (Belaïd, 2024; Sajjad et al., 2024).

However, the study found the change of clothing and window openings as less social contributory factor to energy consumption in student housing, but are reflective attitudinal behaviours that supports the theory of planned behaviour. This is not in line with studies in South Korea, China, and Europe who consider these factors are critical in determining energy consumption especially in summer (Bastien et al., 2024; Conradie et al., 2023; Cheng et al., 2024; Du et al., 2021).

On the other hand, increasing significant contributions of psychological drivers such as thermal, visual, health and safety, and acoustic affects energy consumption. According to the analysis, visual comfort recorded the highest effects on energy consumption. This is in line with Appau et al. (2024) who found a high energy use intensity in student housing in Ghana, but dissimilar to other studies who found visual comfort as a driver of thermal sensation than direct influence on energy consumption (Noorzai et al., 2023; Wang et al., 2023). Conceptually, thermal comfort is largely agreed as the primary determinant of energy consumption in residential buildings (Abdollahzadeh et al., 2023; Alghamdi et al., 2022; Xu, 2022). This confirms similar studies in sub-Saharan Africa (Mba et al., 2023; Sholanke et al., 2022; Lamberti et al., 2021) and serves as a

factor the determines the perceive behavioral control of students as indicated in the theory of planned behaviour.

However, in this study, thermal comfort reported the second highest effects on energy consumption in Ghana. Even though this result ranks second, it has high predictive power in the coming future when not checked. Acoustics on the other hand shows the lowest psychological effects on energy consumption. Besides, the assessment of acoustic comfort in student housing has been found as dissatisfied, though, but have not been proven to largely affect energy consumption in student housing (Abdollahzadeh et al., 2023; Dong et al., 2022; Xu et al., 2020).

Physical drivers (PHD) of student behaviours form the fourth driver that showed negative relationship between the energy consumption constructs. This implies that the determinants of energy consumption have an inverse relationship with drivers of PHD indicators. For example, the study found that temperature, noise, room illumination, and odour influenced student energy use behaviours as supported by (Billanes & Enevoldsen, 2022; Moadab et al., 2021). According to Choi et al. (2022) these indicators reported 27% energy savings in sustainable buildings in similar studies in Korea. Among these indicators, room illumination, noise levels, and odour in rooms reported over 90% impact on student energy use behaviours. This is not in line with similar studies Albatayneh et al. (2021) who found that that lowering the window sizes increases illumination when using LED lightening. However, the results on room illumination supports Rucińska and Trząski (2020) a low room illumination in university building. Linking the contributions of odour to other studies, Coggins et al. (2022) established an indirect relationship between occupants' satisfaction of indoor air quality emanating from high pollutant in the building and energy use. Aside, the room illumination and odour, temperature recorded the last impact variable on energy use in this study, which is not in line with Sousa (2021) found high humidity levels, occupants'

density, and temperature in bedrooms as critical and correlated positively with occupants' density and pollutants.

On the other hand, Physiological drivers and Psychological drivers form the second and third drivers that showed positive relationship between the energy consumption constructs. Age, gender, health condition, activity level in building, student's income levels were positive physiological indicators influencing student energy use behaviours. These indicators support similar findings in Lithuania, Austria, and Spain and Netherlands (Azarova et al., 2020, Jakučionytė-Skodiene et al., 2020; Niamir et al., 2020). However, specifics show that age and health conditions influence energy use behaviour among students in Ghana as compared to physical indicators. This is in line with Jian et al. (2022) who also found age as high contribution to energy use behaviour than gender. However, income levels and gender of student housing users reported positive but lower contributions to energy use behaviours in this study than what was observed in Hojnik et al (2021). Psychologically, the study is of the view that the health and safety, the visual, thermal, and acoustic comfort nature of student housing in Ghana affect energy use behaviours. However, these indicators did are not the main the indicators that influence energy use behaviours within the Ghanaian context as compared to (Abdollahzadeh et al., 2022; Liu & Wang, 2022; Santamouris & Vasilakopoulou, 2021; Rijal et. al., 2021) in the developed world.

Situating this study within the theory of planned behaviour, student managers are of the view that personal norm, perceived behavioural control, attitude, and behavioural intentions affects energy consumption. The PLS-SEM analysis showed that perceived behavioural control contributes 90.5% effects on energy consumption in student housing. Followed by attitude, this study confirms (Ajzen, 2002) which postulates that perceived behavioural control accounts for considerable disparity in person actual behaviour. Other scholar has proven that perceived behavioural control

have strong positive impact towards energy savings and appliance usage (Duong, 2023; Harun, 2022). However, it was interesting to find that personal norms and behavioural intentions did not show more explanation power on energy consumption. This confirms why these factors serve as mediating factors than direct drivers in assessing energy saving intentions in other studies (Çakır Yıldırım & Karaarslan Semiz, 2019; Du & Pan, 2020; and D'Oca et al., 2017). Contrary, unlike (Xu et al., 2021; Alipour et al., 2012; Masrahi et al., 2021, and Paul et al. (2016) who reported attitude as major determinant of energy consumption, this study reported it as second major determinant of energy consumption decisions in Ghana.

CHAPTER NINE

4-QUADRANT INTEGRATED FRAMEWORK FOR INDOOR ENVIRONMENTAL ENERGY SUSTAINABILITY IN STUDENT HOUSING IN GHANA

9.1 Introduction

This section presents the answers to the objective (5) five of the study. Thus, the section presents the framework for assessing indoor environmental energy sustainability in Ghana. The framework is presented into three models. Model 1 presents a sub-framework on sustainable housing design. Model 2 describes a sub-framework on indoor environmental energy control. The last framework presents an integrated framework of the study.

9.2 Sustainable student housing design model.

Sustainable student housing design is aimed to reduce cost of energy, increase investors returns, while protecting occupants from environment health risk. The objective of this model (Figure 9.1) is understanding the drivers of sustainable student housing design. Strategies to achieve this objective is presented in the model. According to the analysis, the study found that window design and glazing, indoor circulation space, and gross indoor area were high requirements that contributed negatively to energy consumption. This study confirmed that less concentrations on shape of window glazing, efficiency of window glazing, sun shading geometry, ventilation and acoustic performance are critical to energy consumption in student housing. The effective implantation of this requirements will require the sampling of some on-campus student housing design along with prototyping the designs through testing for expected energy use capacity in the building. Utilizing these requirements by the help of either Revit, EnergyPlus, and other BIM software will be the method for achieving this strategy.

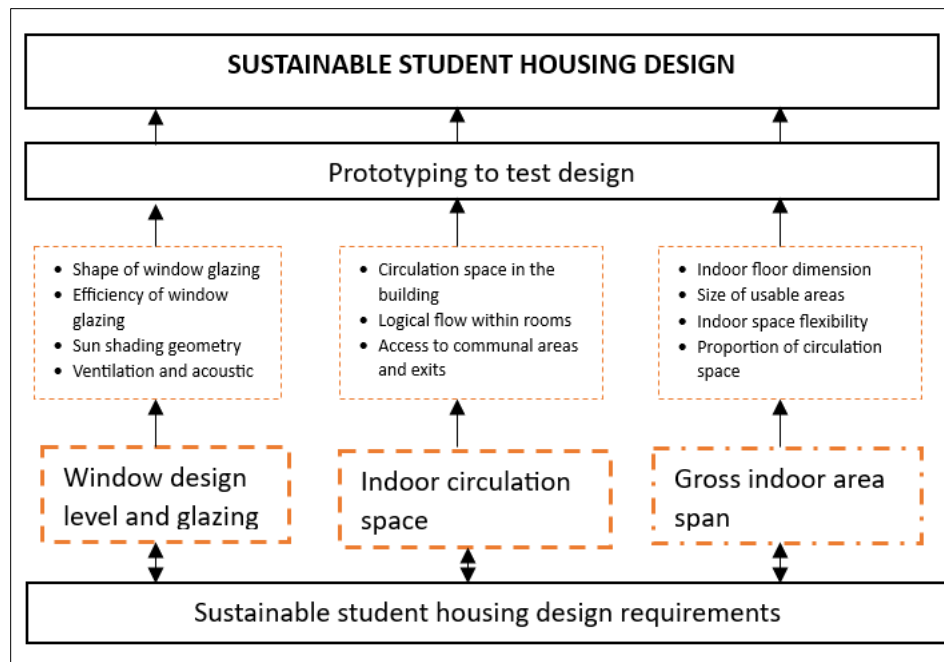


Figure 9.1 Sustainable student housing design sub framework

Source: Author's Construct (2024)

9.3 Indoor environmental energy control

Another main approach of achieving sustainable energy consumption in student housing is through indoor environmental energy control. Literature have supported that aside, the student housing design, student behavioral factors affect energy consumption. In this model (Figure 9.2), the study aims to present the approaches towards indoor environmental energy control in student housing. Strategies of achieving indoor environmental energy control is hinged on student housing energy use factors that influence behavioral aspects of students. These include; social physiological, psychological, contextual, and physical drives. However, the study showed insignificant contributions of contextual driver. To promote enhanced indoor environmental energy control, the study establishes a strong focus on social drivers-social and personal influence, number of students per room, and window opening. In controlling these drivers, students perceived behavioral control, attitude, behavioral intentions, and personal norms influenced positive decisions on energy use in

student housing. However, a high emphasis on student perceived behavioural control will serve as a key method that will drive students' energy use behaviours in Ghana

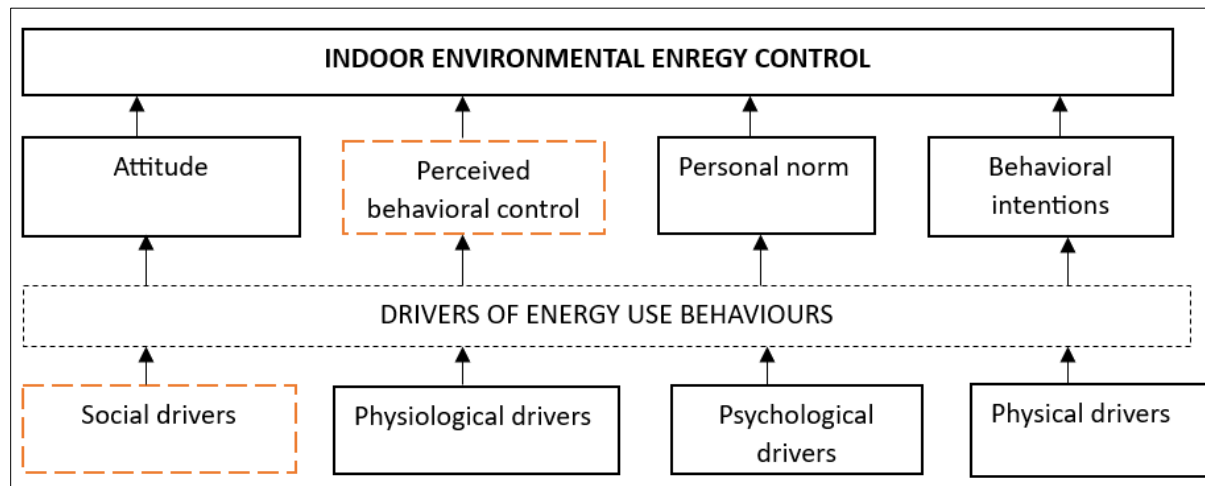


Figure 9.2 sub framework of indoor environmental energy control

Source: Author's Construct (2024)

9.4 Four (4)-quadrant Integrated indoor environmental energy sustainability model

This section presents the overall framework of the study. Taking an overview of model 1 and model 2 in this chapter, this study develops 4-quadrant integrated indoor environmental energy sustainability model (see Figure 9.3). The first quadrant explains the sustainable student design strategies that directly have impact on indoor energy sustainability. Situating this quadrant within the integrated theory of sustainable design, it requires pre-testing and prototyping, which forms the second quadrant of the model. The third quadrant shows the need to largely focus of social drivers which has influence on students perceived energy behaviours. This has largely been confirmed by the theory of planned behaviour. For example, reducing student per room and controlling social and personal influence will serve as a starting point to check indoor environmental energy. Overall, all these quadrants are interconnected to ensure indoor environmental energy consumption in student housing in Ghana.

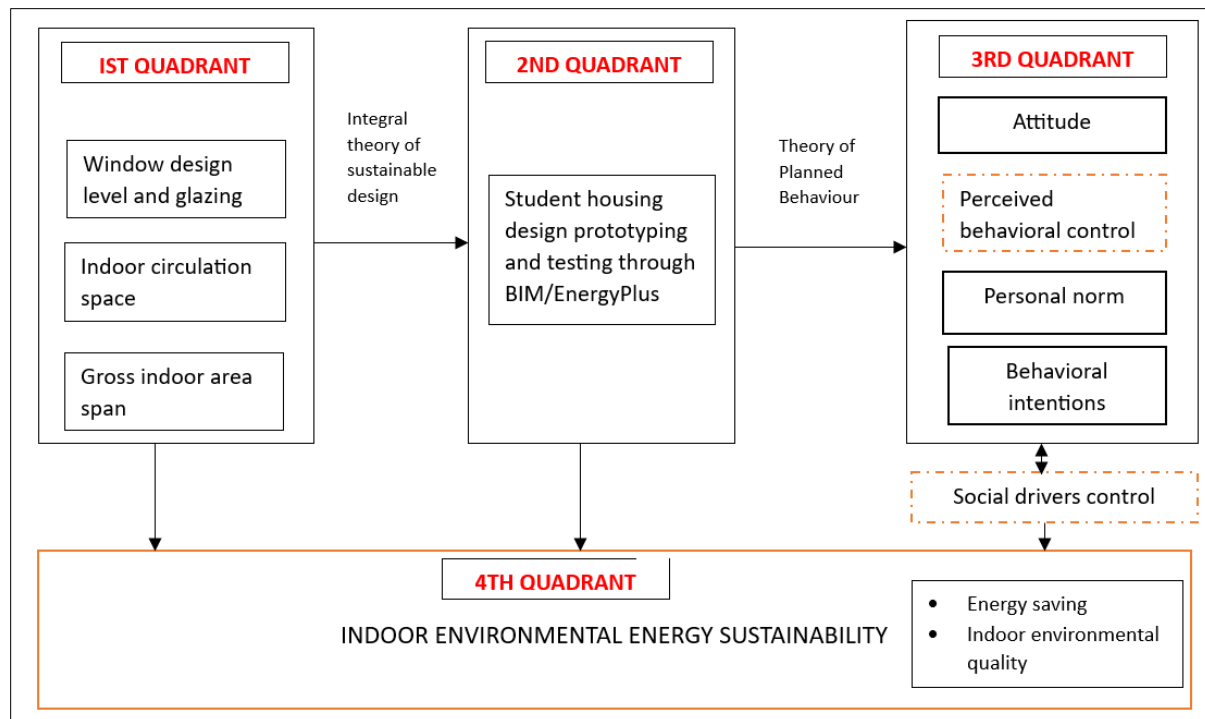


Figure 9.3 4-quadrant Integrated indoor environmental energy sustainability model

Source: Author's Construct (2024)

CHAPTER TEN

CONCLUSIONS AND RECCOMENDATIONS

10.1 Introduction

The study seeks to develop a framework for indoor environmental energy sustainability in student housing in Ghana. With focus on environmental sustainability, the study assessed the sustainable student housing requirements, drivers and barriers of sustainable student housing design, behavioural aspect of student housing energy use, and developed a model for indoor environmental sustainability in Ghana. To achieve this objective, the study used the explanatory mixed- method approach which involved the use of questionnaire survey and focus group discussions. Student housing investors, student housing managers, professional architects, energy experts, and student housing leaders were participants of the study. partial Least Squares Structural Equation model, Exploratory factor analysis, and relative important index, and thematic analysis were the analytical technique adopted. This chapter presents broad conclusions of this study

10.2 Research objective 1

This objective assesses student housing design requirements and its effects on heating and cooling in student housing in Ghana. In this objective, large amount of literature was reviewed to understand the basic requirements in sustainable student housing design. A large amount of these studies was not directly related to student housing, but showed that building envelop, building orientation, building height and floor levels, window glazing and level, design complexity and shape, indoor circulation area, and gross floor span were common in residential buildings in China, Europe, Asia, and North Africa. This study found that there is limited concentration of window glazing and level, indoor circulation area, and gross floor span which negatively affected heating and cooling in student housing in Ghana. the study found that while circulation space in the building and efficient circulation routes and convenience seem paramount in indoor circulation

design strategy, this study finds it as imperative indicator that is expected to increase energy consumption. Aspects of logical flows in rooms and access to communal areas seems though not critical, it can serve as a prediction for energy consumption when not included in designs. Also, increasing lack of attention to shape of window glazing, efficiency of window glazing, sun shading geometry, and ventilation and acoustic performance of window glazing levels had effects on energy consumption which was similar to studies in hot climatic regions Asia. Aside the results on window glazing, indoor floor dimension, size of usable area, indoor space flexibility, and proportion of circulation space were contributions of gross indoor floor span. Based on the results, this section can conclude that increasing the concentration of all the requirements with much emphasis on indoor circulation space, window glazing and level, and gross indoor floor span has a potential to influence sustainable student housing design in Ghana.

10.3 Research objective 2

This second objective aims to examine the drivers of sustainable student housing designs in Ghana. To achieve this objective the study first conducted a literature review on sustainable student housing. However, most of the reviews were related to green buildings, green financing, sustainable material, and indoor environmental quality. since sustainable student housing designs looks similar to others in literature, the study assessed the drivers of sustainable student housing design using; economic, design, financial, health safety and comfort, all-inclusive, social, knowledge, and market drivers. Using exploratory factor analysis approach, the study found that financial, health, building design, and economic related factors largely drives student housing investors decisions to adopt sustainable student housing designs compared to related studies. Among them, financial indicators such as the high-cost energy and energy sharing mechanisms influences student housing investors to adopt to sustainable student housing designs. Coupled with

that, the study found health, safety, and comfort indicators such as thermal and visual comfort as critical to determining sustainable student housing design adaptation. Building designs related to desires space for studying, and flexibility in the use of stairs were paramount. Issues of climate change and the instances of reduction in waste and water efficiency contributed lastly to economic drivers.

10.4 Research objective 3

This objective aims to assess the gaps of adopting sustainable student housing design in Ghana. compared to other related studies in the global north, regulatory, financial, knowledge, economic, environmental, and cultural barriers affect the implementation of sustainable housing. Based on evidence of this variables, this study assessed the barriers of implementation of sustainable student housing design. Using the EFA approach, the study found that the perception of upfront investment costs in purchase of sustainable building materials, long payback period and investment risks, investors knowledge about building lifecycle-efficient energy solutions and running cost, the lack of knowledge on profitability and cost of indoor sustainable student housing, long product lifecycles (buildings and materials), inadequate appropriate skills for managing sustainable student housing design (eg. communication, awareness, experience, negotiation, leadership, and lateral thinking, and lack of consistent regulatory framework and high cost of building materials are critical barriers affecting investors decisions to invest in sustainable student housing design. This was confirmed by experts' views in the focus group discussion. Unlike other studies in the global north where regulatory concerns, financial, and environmental concerns largely affect the implementation of sustainable housing, this study has shown otherwise.

10.5 Research objective 4

This objective was aim to assess the behavioral control of students towards indoor environmental energy use in student housing in Ghana. Under this section, the level of awareness, drivers of student energy use behaviours, and the impact of these behaviours on energy consumption in Ghana were analyzed. Descriptive statistics report that university students understanding of sustainable buildings were limited. For instance, the study found that students understand the benefit and consequences of using sustainable energy. Aside, students understand sustainable energy as a solution to natural resource depletion, energy saving has long-term effect on future generation, and energy efficiency have effects on global warming and greenhouse effect. This was more related to sustainability in the abstract term. However, the study found that sustainable issues related to buildings were less understood which had implications on energy use behaviours. Using the PLS-SEM, the study reported that social drivers had higher contributions to determine behavioural factors such as attitude, perceived behavioural control, behavioural intentions, and personal norms. This contributed to over 10% and above energy consumption in student housing in Ghana. Aside, the relative important index analysis showed that indoor thermal and visual comfort indicators did not contribute to high satisfaction which has the potential to influence students perceive behavioral control, attitude, intentions, and personal norms of energy consumption decisions in Ghana

10.6 Research objective five

This last objective was to develop a framework for assessing indoor environmental energy sustainability in Ghana. Considering the 4-quadrant integrated framework, it can be concluded that both experts and quantitative results confirmed this model. However, to promote enhanced indoor environmental energy control, the study establishes a strong focus on social drivers-social and

personal influence, number of students per room, and window opening. In controlling these drivers, students perceived behavioral control, attitude, behavioral intentions, and personal norms influenced positive decisions on energy use in student housing.

10.7 Contributions of the study

This study has made significant contributions to the field of sustainable buildings and design. The study made contributions towards advancement of methodology, theory, and practice in sustainable student housing designs. Primarily, the most substantial contributions of the study lie in developing a 4-quadrant indoor environmental sustainability framework in student housing in Ghana.

10.7.1 Contributions of integrated indoor environmental energy sustainability to industry

The 4-quadrant integrated indoor environmental energy sustainability shows a great contribution to knowledge in Ghana which can be tested in other sub-Saharan Africa countries. This framework shows the relevance of assessing the design requirements gaps, initiating prototyping strategies, and controlling student energy use behaviour at the end. The model identified indoor circulation space, window level and glazing, and gross indoor space as gaps in existing literature in sustainable student housing designs within the sub-Saharan Africa context. Situating the framework within the integral theory of sustainable design and theory of planned behaviour enhances the understanding of nature of energy use behaviour and design requirements towards sustainability in the student housing market in Ghana. The combination of the theories in the framework has shown a high concentration of social drivers as a detrimental variable that can influence student energy use behaviours even when prototyping provides positive values of sustainability expectations in the design.

10.7.2 Theoretical contributions

Theoretically, the study contributes to concepts related to drivers, barriers, and behavioural control of energy sustainability in student housing. Despite the high reliance and undefined indicators related to financial, environmental, social, and regulatory drivers of sustainable buildings in most sustainable building studies, this study conceptualises these varied drivers into financial, economic, market, all-inclusive design, health safety and comfort, and knowledge or awareness, which novel especially within the sustainable student housing design context. Aside the factors other than financial and economic, this study health, safety, and comfort and building designs related to desires space for studying were unique drivers that adds to literature in sustainable building. Other results emanating from barriers of sustainable student housing design showed more socially related compared to finance, regulations, environmental, and economic as see in literature related to sustainable buildings. This is a new developing in sustainable building discourse.

Earlier review of the integral theory of sustainable design appeared to be limitedly applied in architecture, and no application in construction management. The application of this in this study is a major contribution. Aside, the integral theory was aimed to overawed critical areas of; analysis and creativity, design and technology, art and science, and the reasoning that has exceeds the design disciplines for the past years. Although it acknowledged the purpose and merit of building designs and environmental sustainability, this study found that focusing on design alone does not constitute indoor environmental sustainability in student housing perspective. For instance, the large support for building envelope and orientations, geometry and shape, glazing and façade inclusions, building height, circulations layouts, and interior span dimension affect indoor energy sustainability in most studies in the global north was not common in the student housing context.

Undoubtedly, the study contributes to the integral theory through the 4-quadrant model that aims to achieve indoor environmental performance. In support, the theory of planned behaviour has been widely used in sustainable building studies. However, most of these studies find personal norms and behavioural intentions as critical. In this study, it was observed that students perceived behavioural control were higher which contributed to the theory of planned behaviour.

10.7.3 Methodological contributions

Methods of developing frameworks for sustainable buildings are varied in literature. Large number of studies rely on the use BIM, regression models, artificial intelligence, machine learning, Exploratory factor analysis, and spatial statistics. Within the context of Ghana, scholars have used regression models, BIM, and EFA to conduct studies related to sustainable buildings. No study has employed the use mixed methods that hinges on focus group discussion and questionnaire survey in sustainable student housing. The application of EFA, relative importance index, and partial least square structural equation model provide a robust methodological contribution towards determining sustainable student housing design and its effects on energy consumption, drivers, barriers, and student behavioural aspect of energy use in student housing. With respect to, EFA analysis, the study used principal component method which reported accurate rotated variances explained that defined the critical drivers and barriers of sustainable student housing design compared to factor analysis used in other studies. Moreover, combining the descriptive analysis with the relative important index to assess the level of awareness of student's attitude towards building energy control systems provided valuable outcomes. Again, studies related to energy sustainability in student housing are usually conducted using BIM and machine learning technique in the global north. Within the Africa context, little studies have used the PLS-SEM analytical technique.

Integrating the PLS-SEM analysis in the study helped to determine the impact of sustainable student housing requirements on heating and cooling. Conceptually, this is a methodological contribution than practical in other studies in global north. Similarly, using behavioural factors as mediating determinants of drivers of building control energy use and energy consumption in objective 4 is distinct from using it alone as a determinant of energy consumption as seen in other studies. Further, in the PLS-SEM analysis the use of the Fornell and Larcker criterion and the Heterotrait-Monotrait Ratio (HTMT) of the correlations showed the robustness of the models compared with many studies who only report the Fornell and Larcker criterion for discriminant validity assessment. Aside, the assessment of model fit using goodness of fit index, Root Mean square Error of Approximation, comparative fit index, Tucker-Lewis's index, and Normal fit index, and Incremental fit index, which is common in Covariant-Based Structural equation model than in PLS-SEM, this contributed to robustness of the study. Moreover, statistically recording high internal reliability values shows the perfectness of the model which can be replicated in other studies. Finally, the systematic assessment of the quality checks of the model prior to model testing contributed to statistically significant results for objective 1 and 4 which means that the data was good and can be replicated to validate similar studies.

10.7.4 Practical contributions

This section discusses the practical implications of the study. Thus, the relevance of the study to student housing investors, experts, student housing managers, architects, and students living in university housing. The 4-quadrant framework will serve as foundational framework for university management and planning institutions overseeing the implementation of sustainable student housing in Ghana. Within the context of core implementers, the understanding of the critical design requirement necessary to ensure indoor sustainable energy would be beneficial,

especially to architects. The benefit can be classified into three ways. First, architects would appreciate the consideration of indoor floor measurement that can enhance indoor air-circulation, ensure easy movement within the building, and ensure convenient ventilation routes. Second, architect would appreciate the need to consider window glazing measurements that provide energy sustainability, taking into account the building orientation, typed of glazed material, and glazing window height. Moreso, increasing understanding the gross floor span is essential to architects. Additionally, the considering the high energy consumption in student housing in Ghana, introducing window glazing with high levels that allows ventilation in student housing will positively contributing to energy efficiency in Ghana. At best, this framework underscores the need to consider the shape of window glazing, the efficiency of window glazing, and the sun shading geometry requirements in sustainable student housing design. Further, literature showed a high energy use intensity in student housing in Ghana. This framework confirms this claim considering the impact of gross indoor span as a critical requirement towards sustainable student housing. At best, taking into account indoor floor dimension, proportion of circulation space, space flexibility, and size of usable areas attribute to energy saving potentials that can be enhanced in sustainable student housing design decisions.

The partial least square structural equation model showed that the negligence of key requirements in designing sustainable student housing contributes negatively to heating and cooling in Ghana. Aside, this EFA analysis did not affirm regulation as a major barrier to adopting sustainable student housing. This implies, student housing investors can take this opportunity to invest in sustainable student housing design. On the flipside, the increasing acknowledgement of social and financial barriers that focus on complexity of sustainable designs, long pay-back period, lack of standardization of sustainable student housing designs, lack of student housing market demand for

sustainable building, serves as a call to architect. Moreover, it is essential to emphasize that in as much student's attitude, behavioural intentions, the perceived behavioural control, and personal norms influence energy consumption, the factors that influence these behaviours in this study will serve as the first point after post-prototyping of design. This is a practical implication that can control energy sustainability in the Ghanaian student housing market.

10.8 Recommendations

10.8.1 Methodology recommendation

The use of the mixed method approaches was adopted to explore and confirm relevant concepts related to student housing design, its drivers, barriers, and student behavioural aspect of energy consumption. The focus group discussion provided valuable insights that confirm the quantitative findings from architects, student housing managers, and student housing leaders. The EFA and SEM was used because of the strength over other inferential statistical technique such as ANOVA and regression, which can be replicated in similar studies.

The EFA analysis reported descriptive results which included environmental drivers and barriers but did not report factor loading of its indicators which is likely attributed to the lack of reliable response for these indicators. Therefore, increasing the sample size of student housing investors in similar studies in other Sub-Saharan Africa country like Nigeria and others will enhance the EFA results. Notwithstanding the sample size, similar study can use the Confirmatory Factor Analysis (CFA) to confirm these findings.

Moreover, the study only reported direct effects of student housing requirements on sustainable student housing design using the PLS-SEM. Therefore, future studies should consider the indirect effect by introducing a moderating design variable that influence sustainable student housing design. Aside, because the study did not determine the unobserved heterogeneity between observed

covariance and predicted values of the student behavioural factors and its drivers of energy consumption, it would be important to further test the model using Covariance Based Structural Equation Model (CB-SEM). More so, the focus group discussion showed valuable results but limited, considering the number of energy experts. Therefore, future studies can increase the sample size of experts and adopt a face-to-face or telephone interviews to enhance the study.

10.8.2 Theoretical recommendation

Earlier review shows vast number of studies within sustainable buildings. Studies have confirmed the increasing demand for sustainable student housing especially within the developing world. Despite these studies, there is lack of framework to that explains the processes of achieving sustainability in student housing. Evidence of this study has filled this gap within the built environment. Delving on the 4-quadrant framework of the study, the first quadrant require that design prototyping is not conducted in isolation. Thus, feedback from architects on the critical sustainable student housing design requirements must be conducted regularly to understand evolving indicators describing these requirements. The second quadrant confirms large number of studies that used BIM to understand sustainability in buildings and validated by energy experts during the focus group discussion. The third quadrant showed the need to assess the behavioural aspect of student after prototyping of design which is usually not common in literature. Moreover, the study identified that social, financial, knowledge, and regulatory barriers as barriers of sustainable student housing design in Ghana.

Similarly, social, financial, health and safety comfort formed essential drivers of sustainable student housing design adaptation in Ghana. Based on these, studies related to sustainable building in any asset class in Ghana should use these drivers as a guide in the research. Further, testing the theory of planned behaviour in this study showed that the behavioural premise of the theory can

only trigger the impact on energy consumption through physical, physiological, contextual, social, and physiological drivers. Therefore, it is recommended that future discussion should evaluate the possibility towards an enhanced theory beyond the theory of planned behaviour.

10.8. 3 Policy recommendation

The policy recommendation is based on the 4-quadrant framework developed by this study. the policy recommendations are indicated below:

1. Sustainable student housing design can be enhanced through the compliance of sustainable building design requirements as enshrined in the Ghana Building code (2018). Most attention should largely be based on indoor environmental sustainability. At best, a collaboration between the Ghana energy commission and the physical planning unit can enforce the compliance.
2. Expert view showed that most student housing use low standard electric wire cables which cause gadget burn and increase consumption. Controlling this will require strict monitoring and evaluation of electric wiring of student housing by the Ghana energy commission
3. To ensure large adaptation of sustainable student housing design, governments must make efforts to reduce the cost of sustainable building materials and provide low interest rate to financial institutions. This will enable student housing investors to withstand the financial barriers of assessing loans for construction.
4. Due to the low level of awareness of sustainable student housing design, the Ghana energy commission must focus The education on the student housing market.
5. The study shows that sustainable building is emerging in Ghana. Therefore, it is importance for the architect's council of Ghana to enhance The education on emerging sustainable design tools. This would have positive impact in student housing design.

6. Considering the emergence of sustainable student housing in Ghana, the government should support research studies in sustainable student housing which would serve as a basis to develop policies on sustainable buildings in Ghana in future.
7. University management should ensure that emerging on-campus student housing are sustainable to avoid increasing energy debt. This can be done through expert review of architectural design at the pre-development stage of each university campus.

10.8.4 Practical recommendations

1. To ensure sustainable student housing, it is recommended that student housing managers reduce the room occupancy. This when done will reduce the impact of building services control systems, outdoor visual thermal control systems, indoor visual and thermal control systems, and appliance and gadget control systems on energy consumption in student housing.
2. Also, the ripple effect of student's attitude towards appliance management and gadget use requires that, student housing managers adopt automated systems that puts appliances on standby mode and control air-condition use.
3. At the moment, smart meters should be installed in student housing to remove the burden of energy cost to student housing investors.
4. To ensure indoor environmental energy sustainability, energy sustainability rules should be part of student housing indoor etiquettes. This should focus largely on use of energy saving bulbs and encouraging the use of artificial lighting and ventilation.
5. To conclude, it is recommended that students should be educated on the importance of ensuring sustainability related to buildings than understanding sustainability in the abstract term. This should be part of the orientation sessions for first year students.

10.9 Limitations of the study

The study contributed to the gap in existing research on developing sustainable student housing design. Despite the knowledge contribution, the study observed some limitations.

1. This study focused on environmental sustainability which forms only one pillar of the sustainability framework. Future studies should also focus on social, economic, and institutional sustainability of energy efficiency related to student housing. This is a grey area that have more gaps to explore.
2. Also, the literature review was more focused on similar studies in Asia, Europe, and North Africa. This is a limitation which requires that further studies should review studies in South, West, East, and Central Africa to have a comprehensive gap in review.
3. Methodologically, the inability to get consent from university of Ghana, University of Professional studies, and Cape coast technical university was a limitation. These universities feature among other public universities that have large on-campus student housing market. Also, the questionnaire did not provide enough opportunity for investors, student housing managers, and students to freely express themselves on the reasons behind the indicators. Moreover, constituting one focus group discussion is not enough to understand expert view in sustainable student housing. constituting another focus group discussion with architects would have complimented findings from energy experts.
4. Finally, the cost for gatekeeper's letter was an impediment to covering other universities and technical universities in the study.

10.10 Recommendation for Further Research

1. The study opens opportunity for future studies in social, economic, and institutional frameworks on student housing design. Social sustainability aspect would need to

concentrate on how sustainable design tackles inclusiveness, social integration, and control of the challenges that may emanate from energy cost sharing formulae in university student housing. economic sustainability would also need to investigate the relationship between sustainable design and energy pricing. Aside, there would be the need to examine the components of design that influences energy cost management on both the investors and students' perspective. other can also explore institutional frameworks on sustainable student housing design and its contributions to building performance and academic output

2. The assessment of effects of drivers of sustainable student housing was conducted using questionnaire and focus group discussion. Future studies should assess the energy consumption capacity of selected student housing in Ghana using BIM software's. Detail aspects should be based on window efficiency and design levels, indoor circulation and ventilation systems, and building orientation. This will be able to confirm that compliance contributions of student housing requirements and student behavioural drivers affects energy consumption above 10%. This is a major research project that needs to be conducted.
3. Also, the study recorded contrary findings that influences the requirements, drivers, and barriers of sustainable student housing design as seen in the global north. Conducting similar studies in other part of Africa countries would help to confirm the findings of this study. Closest country within the sub-Saharan Africa Country, is Nigeria.
4. Further, future studies should test the 4-quadrant framework in both Northern and Southern Ghana to help provide unique recommendations for indoor environmental energy sustainability.

5. Additionally, future studies should include off-campus purpose-built student housing to provide a complete understanding of indoor environmental energy sustainability in the student housing market in Ghana.
6. Finally, future studies should validate the 4-quadrant framework of this study.

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APPENDICES

APPENDIX A



APPENDIX 1: This questionnaire is for Architects

QUESTIONNAIRE SURVEY ON FRAMEWORK FOR EVALUATION OF ENERGY SUSTAINABILITY IN CHANGING UNIVERSITY STUDENTS' HOUSING IN GHANA

Good day Sir/Ma,

I hope you are doing well. I am **Appau Williams Miller**, a Doctoral student in the Department of Construction Management and Quantity Surveying, Durban University of Technology, Steve Biko Campus, Durban, South Africa. I am researching the *“Framework for evaluation of energy sustainability in changing university students’ housing in Ghana”*. This study aims to develop a Framework for evaluation of energy sustainability in changing university students’ housing in Ghana to facilitate an efficient energy and consumption. This questionnaire seeks to:

- i. To examine building design requirements, drivers, and barriers of sustainable student housing design and its influences on indoor environmental energy sustainability in Ghana

You are kindly requested to complete the questionnaire. There are no names required in this survey. Participation is voluntary, and you can withdraw at any time without negative consequences. The questionnaire will take about 10 to 20 minutes to complete. The collected data will be treated anonymously, and the survey findings will only be used for research purposes. Please note that there are no risks, current or anticipated, to you as a participant in this research. Your co-operation will be greatly appreciated. For any queries or comments regarding the survey, please contact

22384333@dut4life.ac.za, cell: +233245452406 and irukaA@dut.ac.za, cell: +27784784636

Your completion of the survey will be understood to meet the requirements of the informed consent according to the following: I have been invited to participate in the study mentioned earlier and have also been informed about my involvement in the research and what required of me.

- My participation in this research is voluntary.
- I may withdraw from the research at any time with no negative consequences for myself.
- This study has been described to me in a language that I understand.
- My answers will be kept confidential.
- I agree that my responses from the questionnaire can be used for the research.

Thank you in anticipation of your positive response to this request

APPENDIX B

RESEARCH INSTRUMENT

Preamble: The research questionnaire is part of my PhD study at Durban University of Technology, South Africa. The study seeks to develop a framework for the evaluation of energy sustainability in changing university student housing in Ghana. Your responses to this questionnaire will be treated with confidentiality, privacy, and assist me to complete my Ph.D. within time. Your assistance is highly appreciated

The following are the key drivers of design requirements for indoor environmental energy sustainability. Please, kindly rate the critical factor as a driver of design requirements in student housing for indoor environmental energy sustainability in Ghana.

Variables/ Critical factors	Very low factor		Low factor		Moderate factor		High factor		Very high factor	
	1	2	3	4	5	6	7	8	9	10
Building envelope										
Building orientation										
Building design and geometry										
Building height and storey levels										
Window glazing and efficiency										
Indoor circulation space										
Gross floor span/dimensions										

Kindly rate the levels of consideration of student housing regarding requirements of elements in sustainable building designs.

Variables/ level of consideration for sustainable building designs	Strongly do not considered		Not considered		Somewhat considered		Normally Considered		Strongly considered	
	1	2	3	4	5	6	7	8	9	10
Building orientation										
Related to Wind and Sun										
Related to building View										
Related to privacy										

Shielding from external noise										
Building envelop										
Building Massing/ form										
Glazing requirements										
Nature of façade material										
Design complexity and shape										
Building design efficiency										
Building shape complexities										
Building environmental performance										
Building compatibility of external environment										
Building design levels and height										
Average building storey height										
Number of floor levels in building										
Building functionality and use										
Building accommodates vertical movement										
Indoor circulation design										
Circulation space in the building										
Logical flow within rooms										
Access to communal areas and exits										
Efficient circulation routes and convenience										
Window design and glazing										
Shape of window glazing										
Efficiency of window glazing										
Sun shading geometry										
Ventilation and acoustic performance										
Gross indoor area span										
Indoor floor dimension										
Size of usable areas										

Indoor space flexibility										
Proportion of circulation space										

In your opinion how does sustainable building design impact the concept of indoor environmental energy sustainability in student housing in Ghana? Please, answer the question by placing 'X' in the appropriate box below.

Variable/ level of impact	No impact		Low impact		Medium impact		High impact		Very high impact	
	1	2	3	4	5	6	7	8	9	10
Impact of Sustainable building design on indoor environmental energy sustainability in student housing in Ghana										

Kindly rate the levels of impact of sustainable student housing design on heating and cooling systems.

Variables/ level of consideration for sustainable building designs	Strongly do not considered		Not considered		Somewhat considered		Normally Considered		Strongly considered	
	1	2	3	4	5	6	7	8	9	10
Building orientation										
Related to Wind and Sun										
Related to building View										
Related to privacy										
Shielding from external noise										
Building envelop										
Building Massing/ form										
Glazing requirements										

Nature of façade material										
Design complexity and shape										
Building design efficiency										
Building shape complexities										
Building environmental performance										
Building compatibility of external environment										
Building design levels and height										
Average building storey height										
Number of floor levels in building										
Building functionality and use										
Building accommodates vertical movement										
Indoor circulation design										
Circulation space in the building										
Logical flow within rooms										
Access to communal areas and exits										
Efficient circulation routes and convenience										
Window design and glazing										
Shape of window glazing										
Efficiency of window glazing										
Sun shading geometry										
Ventilation and acoustic performance										
Gross indoor area span										
Indoor floor dimension										
Size of usable areas										
Indoor space flexibility										
Proportion of circulation space										

The following are the key drivers of adaptation of sustainable student housing design and implementation in Ghana. Please, kindly rate the key drivers in the table below;

Key drivers/ variables	Very low factor		Low factor		Moderate factors		High factor		Very high factor	
	1	2	3	4	5	6	7	8	9	10
Economic										
Design										
Institutional/government policy										
Financial drivers										
Health, safety, and comfort										
All-inclusiveness and social										
Market										
Knowledge/awareness										
Others if any: State and rate it:										

In your opinion, to what extent do the drivers of sustainable student housing design influence indoor environmental energy sustainability in Ghana?

Variables/ drivers influence	Not influential factor		Low influential factor		Moderate influential factor		High influential factor		Very high Influential factor	
	1	2	3	4	5	6	7	8	9	10
Economic										
Climate change										
Affordability of building design.										
The emergence of active and passive design e.g. Use of air conditioner										
Building energy efficiency										
Reduction in waste and water efficiency										
Building designs	1	2	3	4	5	6	7	8	9	10

Building layout for student movements										
Aesthetics										
Desired space for studying										
Flexibility in the use of stairs and all-inclusiveness										
Institutional/government policy drivers	1	2	3	4	5	6	7	8	9	10
Government policy on the adaptation of sustainable buildings										
student housing management on the adaptation of energy efficient										
Financial incentives and subsidies for using renewables										
Sustainable housing as part of climate action goal										
Financial drivers										
The high energy cost for students										
Energy sharing mechanism among tenants										
Desire to reduce energy consumption										
Life cycle cost										
Reduction in construction cost										
Health, safety, and comfort drivers										
Thermal comfort eg. Heating and cooling										
Visual Comfort eg. Lighting design and natural lighting										
Comfortable indoor health										
Safety in the use of energy appliances										
All-inclusiveness and social drivers										

Indoor energy appliances effects on students with disability										
Collaborative studying indoor environment										
Disability quality of life (health and comfort										
Inclusivity and physical accessibility										
Student and investors awareness of sustainable housing										
Market drivers										
Emergence of sustainability in the student housing market										
Student housing owners' readiness to adopt to sustainable buildings										
Availability of financial options tailored for sustainable building materials										
Increasing awareness for environmentally friendly and energy efficient student housing										
Knowledge/awareness drivers										
Lack of know-how on sustainable student housing										
Innovations in use of sustainable building materials										
Ideas from previous research studies on sustainable students housing										
Replicability and knowledge sharing among student housing										
Environmental drivers										
Reduced air pollution through clean building materials										
Ecosystem and biodiversity preservation										

Promoting reuse and recycling of materials										

The following are the key barriers of adaptation of sustainable student housing design and implementation. Please, kindly rate the key barriers in the table below;

Variables / Barriers factors	Very low barrier		Low barrier		Moderate barrier		High barrier		Very high barrier	
	1	2	3	4	5	6	7	8	9	10
Social barriers										
Regulatory barriers										
Financial barriers										
Knowledge and common language										
Economic barriers										
Environmental barriers										
Others if any: State and rate it:										

In your opinion, kindly rate how the sub-elements/ components of barrier factors in *QI* that affect the adaptation of indoor environmental energy sustainability designs among student housing in Ghana

Variables / Barrier factors affecting the adaptation of indoor environmental energy sustainability designs	No barrier affects		Low barrier affect		Moderate barrier affects		High barrier affects		Very high barrier affects	
	1	2	3	4	5	6	7	8	9	10
Social barriers										
Complexity of sustainable designs										
Long product lifecycles (buildings and materials)										
Technical challenges and material recovery										
Lack of standardization of sustainable student housing designs										

lack of market demand and lack of demand from companies and society for sustainable building										
Regulatory barriers	1	2	3	4	5	6	7	8	9	10
Lack of consistent regulatory framework										
Obstructing laws and regulations										
Low regularity requirements										
Lack of energy audit and assessment										
Financial barriers	1	2	3	4	5	6	7	8	9	10
High upfront investment costs in purchase of sustainable building materials										
High building material prices										
Limited funding										
Long payback period and investment risks										
Knowledge and common language	1	2	3	4	5	6	7	8	9	10
Lack of knowledge on profitability and cost of indoor sustainable student housing										
Inadequate appropriate skills for managing sustainable student housing design (eg. communication, awareness, experience, negotiation, leadership, and lateral thinking)										
Lack of knowledge of environmental effects										
Knowledge about building lifecycle-efficient energy solutions and running cost										
Economic barrier										
Climate change										
Affordability of building design.										

The effects of active and passive design e.g. Use of air conditioner										
Building energy efficiency										
Effects on waste and water efficiency										
Environmental barrier										
Health risk										
Environmental pollution										
Effects on ecosystem										



APPENDIX 2: This questionnaire is for Student housing investors

QUESTIONNAIRE SURVEY ON FRAMEWORK FOR EVALUATION OF ENERGY SUSTAINABILITY IN CHANGING UNIVERSITY STUDENTS' HOUSING IN GHANA

Good day Sir/Ma,

I hope you are doing well. I am **Appau Williams Miller**, a Doctoral student in the Department of Construction Management and Quantity Surveying, Durban University of Technology, Steve Biko Campus, Durban, South Africa. I am researching the *“Framework for evaluation of energy sustainability in changing university students’ housing in Ghana”*. This study aims to develop a Framework for evaluation of energy sustainability in changing university students’ housing in Ghana to facilitate an efficient energy and consumption. This questionnaire seeks to:

- i. To identify the drivers and barriers of adopting sustainable student housing design in Ghana

You are kindly requested to complete the questionnaire. There are no names required in this survey. Participation is voluntary, and you can withdraw at any time without negative consequences. The questionnaire will take about 10 to 20 minutes to complete. The collected data will be treated anonymously, and the survey findings will only be used for research purposes. Please note that there are no risks, current or anticipated, to you as a participant in this research. Your co-operation will be greatly appreciated. For any queries or comments regarding the survey, please contact

22384333@dut4life.ac.za, cell: +233245452406 and irukaA@dut.ac.za, cell: +27784784636

Your completion of the survey will be understood to meet the requirements of the informed consent according to the following: I have been invited to participate in the study mentioned earlier and have also been informed about my involvement in the research and what required of me.

- My participation in this research is voluntary.
- I may withdraw from the research at any time with no negative consequences for myself.
- This study has been described to me in a language that I understand.
- My answers will be kept confidential.
- I agree that my responses from the questionnaire can be used for the research.

Thank you in anticipation of your positive response to this request

The following are the key drivers of adaptation of sustainable student housing design and implementation in Ghana. Please, kindly rate the key drivers in the table below;

Key drivers/ variables	Very low factor		Low factor		Moderate factors		High factor		Very high factor	
	1	2	3	4	5	6	7	8	9	10
Economic										
Design										
Institutional/government policy										
Financial drivers										
Health, safety, and comfort										
All-inclusiveness and social										
Market										
Knowledge/awareness										
Others if any: State and rate it:										

In your opinion, to what extent do the drivers of sustainable student housing design influence indoor environmental energy sustainability in Ghana?

Variables/ drivers influence	Not influential factor		Low influential factor		Moderate influential factor		High influential factor		Very high Influential factor	
	1	2	3	4	5	6	7	8	9	10
Economic										
Climate change										
Affordability of building design.										
The emergence of active and passive design e.g. Use of air conditioner										
Building energy efficiency										
Reduction in waste and water efficiency										
Building designs	1	2	3	4	5	6	7	8	9	10

Building layout for student movements										
Aesthetics										
Desired space for studying										
Flexibility in the use of stairs and all-inclusiveness										
Institutional/government policy drivers	1	2	3	4	5	6	7	8	9	10
Government policy on the adaptation of sustainable buildings										
student housing management on the adaptation of energy efficient										
Financial incentives and subsidies for using renewables										
Sustainable housing as part of climate action goal										
Financial drivers										
The high energy cost for students										
Energy sharing mechanism among tenants										
Desire to reduce energy consumption										
Life cycle cost										
Reduction in construction cost										
Health, safety, and comfort drivers										
Thermal comfort eg. Heating and cooling										
Visual Comfort eg. Lighting design and natural lighting										
Comfortable indoor health										
Safety in the use of energy appliances										
All-inclusiveness and social drivers										

Indoor energy appliances effects on students with disability										
Collaborative studying indoor environment										
Disability quality of life (health and comfort										
Inclusivity and physical accessibility										
Student and investors awareness of sustainable housing										
Market drivers										
Emergence of sustainability in the student housing market										
Student housing owners' readiness to adopt to sustainable buildings										
Availability of financial options tailored for sustainable building materials										
Increasing awareness for environmentally friendly and energy efficient student housing										
Knowledge/awareness drivers										
Lack of know-how on sustainable student housing										
Innovations in use of sustainable building materials										
Ideas from previous research studies on sustainable students housing										
Replicability and knowledge sharing among student housing										
Environmental drivers										
Reduced air pollution through clean building materials										
Ecosystem and biodiversity preservation										

Promoting reuse and recycling of materials										

The following are the key barriers of adaptation of sustainable student housing design and implementation. Please, kindly rate the key barriers in the table below;

Variables / Barriers factors	Very low barrier		Low barrier		Moderate barrier		High barrier		Very high barrier	
	1	2	3	4	5	6	7	8	9	10
Social barriers										
Regulatory barriers										
Financial barriers										
Knowledge and common language										
Economic barriers										
Environmental barriers										
Others if any: State and rate it:										

In your opinion, kindly rate how the sub-elements/ components of barrier factors in *QI* that affect the adaptation of indoor environmental energy sustainability designs among student housing in Ghana

Variables / Barrier factors affecting the adaptation of indoor environmental energy sustainability designs	No barrier affects		Low barrier affect		Moderate barrier affects		High barrier affects		Very high barrier affects	
	1	2	3	4	5	6	7	8	9	10
Social barriers										
Complexity of sustainable designs										
Long product lifecycles (buildings and materials)										
Technical challenges and material recovery										
Lack of standardization of sustainable student housing designs										

lack of market demand and lack of demand from companies and society for sustainable building										
Regulatory barriers	1	2	3	4	5	6	7	8	9	10
Lack of consistent regulatory framework										
Obstructing laws and regulations										
Low regularity requirements										
Lack of energy audit and assessment										
Financial barriers	1	2	3	4	5	6	7	8	9	10
High upfront investment costs in purchase of sustainable building materials										
High building material prices										
Limited funding										
Long payback period and investment risks										
Knowledge and common language	1	2	3	4	5	6	7	8	9	10
Lack of knowledge on profitability and cost of indoor sustainable student housing										
Inadequate appropriate skills for managing sustainable student housing design (eg. communication, awareness, experience, negotiation, leadership, and lateral thinking)										
Lack of knowledge of environmental effects										
Knowledge about building lifecycle-efficient energy solutions and running cost										
Economic barrier										
Climate change										
Affordability of building design.										

The effects of active and passive design e.g. Use of air conditioner										
Building energy efficiency										
Effects on waste and water efficiency										
Environmental barrier										
Health risk										
Environmental pollution										
Effects on ecosystem										



APPENDIX 3: This questionnaire is for student housing managers

QUESTIONNAIRE SURVEY ON FRAMEWORK FOR EVALUATION OF ENERGY SUSTAINABILITY IN CHANGING UNIVERSITY STUDENTS'

HOUSING IN GHANA

Good day Sir/Ma,

I hope you are doing well. I am **Appau Williams Miller**, a Doctoral student in the Department of Construction Management and Quantity Surveying, Durban University of Technology, Steve Biko Campus, Durban, South Africa. I am researching the “Framework for evaluation of energy sustainability in changing university students’ housing in Ghana”. This study aims to develop a Framework for evaluation of energy sustainability in changing university students’ housing in Ghana

iii. To assess students’ behavioral control of student housing design systems towards indoor environmental energy sustainability in Ghanaian student housing.

You are kindly requested to complete the questionnaire. There are no names required in this survey. Participation is voluntary, and you can withdraw at any time without negative consequences. The questionnaire will take about 10 to 20 minutes to complete. The collected data will be treated anonymously, and the survey findings will only be used for research purposes. Please note that there are no risks, current or anticipated, to you as a participant in this research. Your co-operation will be greatly appreciated. For any queries or comments regarding the survey, please contact

22384333@dut4life.ac.za, cell: +233245452406 and irukaA@dut.ac.za, cell: +27784784636

Your completion of the survey will be understood to meet the requirements of the informed consent according to the following: I have been invited to participate in the study mentioned earlier and have also been informed about my involvement in the research and what required of me.

- My participation in this research is voluntary.
- I may withdraw from the research at any time with no negative consequences for myself.
- This study has been described to me in a language that I understand.
- My answers will be kept confidential.
- I agree that my responses from the questionnaire can be used for the research.

Thank you in anticipation of your positive response to this request

Please, kindly rate commonest source of sustainable energy usage in student housing in Ghana.

Variables / Source of sustainable energy usage	Very Low energy usage		Low energy usage		Moderate energy usage		High energy usage		Very high energy usage	
	1	2	3	4	5	6	7	8	9	10
Hydro										
Solar										
Geo-Thermal										
Wind										
Bio-fuel										

In your opinion, to what extent is the energy consumption in the student housing in Ghana? Please, answer the question by placing 'X' in the appropriate box below.

Variable/ Energy consumption	Very low energy		Low energy		Moderate energy		High energy		Very high energy	
	1	2	3	4	5	6	7	8	9	10
Extent is the energy consumption in the student housing										

Kindly rate, to what extent at which student attitude toward building control systems influences an indoor environmental energy sustainability in Ghana?

Variables /student attitude and influence on indoor environmental energy sustainability in Ghana	No impact		Low impact		Moderate impact		High impact		Very high impact	
	1	2	3	4	5	6	7	8	9	10
Washing machine cautiously										
Usage of WC buttons during flush										

Using less water in toilets										
Turning the tap off when brushing teeth or washing hands										
Using showers instead of bathing with buckets										
Leaving energy appliances on standby mode										
Turning off lights if they're not in use or needed										
Using energy-saving bulbs										
Using low-energy labelled electrical gadgets										
Thermostat control approach for air conditioning in the building										
Putting air-conditioner off when Opening windows during rainy season										
Putting air-conditioner on when windows open during the dry season										
Closing window blinds or shade during indoor or outdoor activities										
Controlling doors/windows airtightness										
Using artificial lighting in a day										
Using energy-saving bulbs										

In your opinion, how does the relationship between students' interactions with building controls impact on energy consumption in the indoor environment?

Variables/ impact of students' interactions on building control	Very low impact on consumption		Low impact on consumption		Moderate impact on consumption		High impact on consumption		Very high impact on consumption	
	1	2	3	4	5	6	7	8	9	10
Washing machine cautiously										

Leaving energy appliances on standby mode										
Using low-energy labelled electrical gadgets										
Thermostat control approach for air conditioning in the building										
Using energy-saving bulbs										
Closing window blinds or shade during indoor or outdoor activities										
Controlling doors/windows airtightness										
Using artificial lighting in a day										
Putting air-conditioner off when opening windows during rainy season										
Putting air-conditioner on when windows open during the dry season										
Turning off lights if they're not in use or needed										
Usage of WC buttons during flush										
Turning the tap off when brushing teeth or washing hands										
Using showers instead of bathing with buckets										



APPENDIX 4: This questionnaire is for student housing leaders

QUESTIONNAIRE SURVEY ON FRAMEWORK FOR EVALUATION OF ENERGY SUSTAINABILITY IN CHANGING UNIVERSITY STUDENTS'

HOUSING IN GHANA

Good day Sir/Ma,

I hope you are doing well. I am **Appau Williams Miller**, a Doctoral student in the Department of Construction Management and Quantity Surveying, Durban University of Technology, Steve Biko Campus, Durban, South Africa. I am researching the “Framework for evaluation of energy sustainability in changing university students’ housing in Ghana”. This study aims to develop a Framework for evaluation of energy sustainability in changing university students’ housing in Ghana

iii. To assess students’ behavioral control of student housing design systems towards indoor environmental energy sustainability in Ghanaian student housing

You are kindly requested to complete the questionnaire. There are no names required in this survey. Participation is voluntary, and you can withdraw at any time without negative consequences. The questionnaire will take about 10 to 20 minutes to complete. The collected data will be treated anonymously, and the survey findings will only be used for research purposes. Please note that there are no risks, current or anticipated, to you as a participant in this research. Your co-operation will be greatly appreciated. For any queries or comments regarding the survey, please contact

22384333@dut4life.ac.za, cell: +233245452406 and irukaA@dut.ac.za, cell: +27784784636

Your completion of the survey will be understood to meet the requirements of the informed consent according to the following: I have been invited to participate in the study mentioned earlier and have also been informed about my involvement in the research and what required of me.

- My participation in this research is voluntary.
- I may withdraw from the research at any time with no negative consequences for myself.
- This study has been described to me in a language that I understand.
- My answers will be kept confidential.
- I agree that my responses from the questionnaire can be used for the research.

Thank you in anticipation of your positive response to this request

Kindly rate your level of awareness of sustainable energy consumption in student housing in Ghana.

Variables/ Level of awareness on sustainable energy consumption	Very low awareness		Low awareness		Moderate awareness		High awareness		Very high awareness	
	1	2	3	4	5	6	7	8	9	10
Knowledge on practicing water and electricity energy saving in the building										
Understand that energy saving affects productivity and comfort										
Energy efficiency have effects on global warming and greenhouse effect										
Energy saving has long-term effect on future generation										
Sustainable energy is a solution to natural resource depletion										
Sustainable energy use influences the building performance										
Understand the benefit and consequences of using sustainable energy										
Level of information on sustainable energy use										
Availability of energy sustainable buildings on university campus										

The following are the drivers of influence students' behavior towards energy consumption in the building? Could you please rate the drivers in the table below:

Variables/ drivers of influencing students' behavior on energy consumption	Very low influential factor		Low influential factor		Moderate influential		High influential factor		Very high influential factor	
	1	2	3	4	5	6	7	8	9	10
Physical drivers										
Temperature										
Noise										
Room illumination										
Odour										
Contextual	1	2	3	4	5	6	7	8	9	10
Insulation of building										
Ventilation										
Heating systems										
Orientation of building										
Psychological	1	2	3	4	5	6	7	8	9	10
Health and safety										
Visual comfort										
Thermal comfort										
Social	1	2	3	4	5	6	7	8	9	10
Number of students per room, sleeping hours, studying hours										
Window opening										
Cloths changes										
Social and personal influence										
Physiological	1	2	3	4	5	6	7	8	9	10
Age										
Gender										
Health condition										
Activity level in building										
Student's income levels										

The following are the behavioural factor that influence students 'energy use in the building? Could you please rate the drivers in the table below:

Variables/ behavioural drivers	Very low influential factor		Low influential factor		Moderate influential		High influential factor		Very high influential factor	
	1	2	3	4	5	6	7	8	9	10
Behavioural factors										
Personal norm										
Behavioural intentions										
Attitude										
Perceived behavioural control										

Please, how does the behavioural factors above influence the amount of energy consumption in student housing?

Variables/ determinant of energy consumption	Very low consumption		Low consumption		Moderate consumption		High consumption		Very high consumption factor	
	1	2	3	4	5	6	7	8	9	10
Energy consumption										
Increase energy consumption by 1-5%										
Increase energy consumption by increase energy consumption by 6-10%										
Increases energy consumption above 10%										
Reduces energy consumption by 1-5%										
Reduces energy consumption by 6-10%										
Reduces energy consumption above 10%										



APPENDIX 5 Focus group questions guide for energy experts

QUESTIONNAIRE SURVEY ON FRAMEWORK FOR EVALUATION OF ENERGY SUSTAINABILITY IN CHANGING UNIVERSITY STUDENTS'

HOUSING IN GHANA

Good day Sir/Ma,

I hope you are doing well. I am Appau Williams Miller, a Doctoral student in the Department of Construction Management and Quantity Surveying, Durban University of Technology, Steve Biko Campus, Durban, South Africa. I am researching the “Framework for evaluation of energy sustainability in changing university students’ housing in Ghana”. This study aims to develop a Framework for evaluation of energy sustainability in changing university students’ housing in Ghana

i. To identify the drivers, barriers, and requirements of adopting sustainable student housing design in Ghana

Participation is voluntary, and you can withdraw at any time without negative consequences. The discussion will take about 1hr to 2hrs minutes to complete. The collected data will be treated anonymously, and the survey findings will only be used for research purposes. Please note that there are no risks, current or anticipated, to you as a participant in this research. Your co-operation will be greatly appreciated. For any queries or comments regarding the survey, please contact

22384333@dut4life.ac.za, cell: +233245452406 and irukaA@dut.ac.za, cell: +27784784636

Your participation in the discussion will be understood to meet the requirements of the informed consent according to the following: I have been invited to participate in the study mentioned earlier and have also been informed about my involvement in the research and what required of me.

- My participation in this research is voluntary.
- I may withdraw from the research at any time with no negative consequences for myself.
- This study has been described to me in a language that I understand.
- My answers will be kept confidential.
- I agree that my responses from the questionnaire can be used for the research.

Thank you in anticipation of your positive response to this request

APPENDIX 5: semi-structure discussion guide

Section 1: The focus group discussion questions is aimed to assess energy experts' idea on sustainable building design and its related factors and consequences on indoor environmental energy in student housing. Please, the questions are opened for self-expression.

1. How do you the term “indoor environmental energy sustainability?
2. What are the specific requirements necessary achieve indoor environmental energy sustainability?
3. Among the requirements indicated in Q2, which ones among them are key to ensuring indoor environmental energy sustainability?
4. In your opinion, what are the main reasons to adopt sustainable design towards indoor environmental energy sustainability in student housing?
5. How helpful would sustainable building design contribute to indoor environmental energy sustainability in student housing?
6. What are some of reasons for not adapting to sustainable designs in student housing?
7. In what ways will the lack of adaptation of sustainable designs influence indoor environmental energy sustainability in student housing market?
8. How is the building orientation, building envelop, design complexities and shape, building design levels and height, indoor circulation design, window glazing and design, and gross indoor floor area considered in student housing designs.
9. What are the contributions of each of the requirements in 8 contribute to sustainable student housing

APPENDIX C
ETHICAL APPROVALS



**SUNYANI TECHNICAL
UNIVERSITY**

In case of reply please
quote reference number

Our Ref: STU/001GCE/006

Your Ref:

Date: 30/05/2024

Appau Williams Miller
PhD Candidate,
Department of Construction Management and Quantity Surveying,
Faculty of Engineering and the Built Environment
S3 Level 2, Steve Biko Campus,
Durban University of Technology (DUT)
Durban, KwaZulu-Natal, South Africa

Dear Sir,

RE: LETTER OF REQUEST TO CONDUCT RESEARCH

Your letter on the above subject refers.

After careful consideration of your request on the above subject, the Directorate of Works and Physical Development is pleased to grant permission to proceed with your research.

The Estate Unit will provide you with the necessary assistance and trust that you adhere to all relevant policies and guidelines to ensure smooth execution of your research.

For further assistance and clarification, please contact Mr. Jonas Koenyehia on **0242867800**.

Thank you.

Yours faithfully

Samuel Nkétia
Ag. Director of Works

C. K. TEDAM UNIVERSITY OF TECHNOLOGY AND APPLIED SCIENCES

Telephone: +233372095456

E-mail: registrar@ckntas.edu.gh

Website: www.ckntas.edu.gh

Our Ref: 22384333

Your Ref:



Office of the Registrar

P. O. Box 24
Navrongo,
Upper East Region
Ghana

Date: July 18, 2024

William Appau Miller

Dept. of Construction Management & Quantity Surveying
Faculty of Engineering and the Built Environment
Durban University of Technology
Durban, South African



Dear William,

RE: LETTER OF REQUEST TO CONDUCT RESEARCH

Your letter on the above subject, refers.

I write to convey the Vice-Chancellor's approval granting you permission to undertake your research work on "*Framework for evaluation of energy sustainability in changing university students' housing in Ghana, CKT-UTAS, Navrongo*", under the supervision of Dr. Angwo Iruka.

This approval is on condition that your University has granted you ethical clearance to undertake this study. Also, you will be required to ensure that all the ethical considerations are keenly adhered to, and the rights of the students and staff of CKT-UTAS are respected throughout the conduct of your research work

You are not permitted under any circumstance to enter any Hall unaccompanied or without the permission of the Hall Tutors and Head of Estates Management. Please note that, you will be responsible for damages caused to University property as a result of this exercise.

We wish you the best of luck in your research.

Peter Yidana (PhD)
(SAR, Academic Affairs)
for: Registrar

Cc: Dean of Students-CKT-UTAS, Ag. Head, DPDEM-CKT-UTAS, File



request for letter of consent



External

Inbox



The Secretariat - Ghan... 7 May



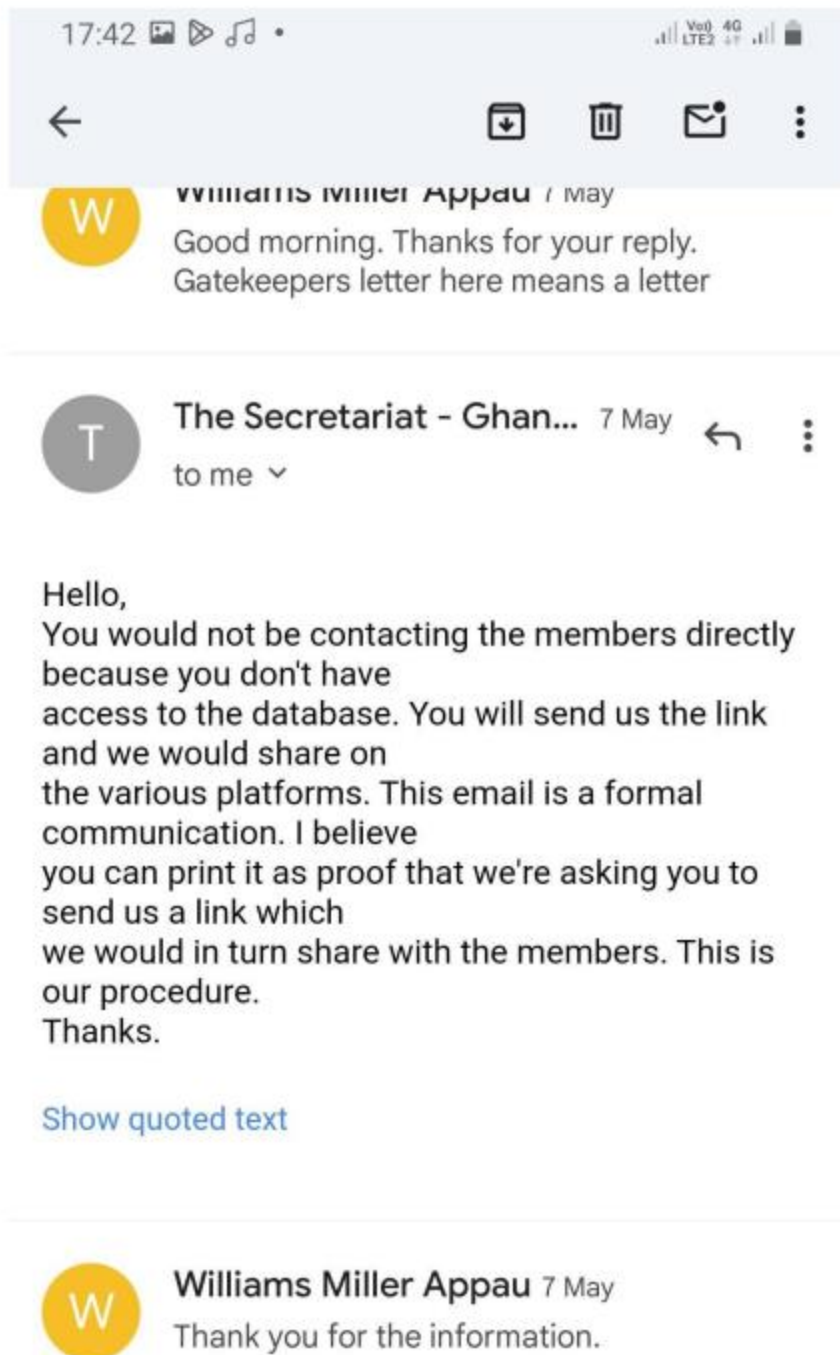
to me ▾

Hello,
We're not sure what you mean by gatekeepers.
We're unable to give you
the contact numbers/emails to meet with
Architects directly as that
would breach the data protection laws of Ghana.
The Estate Departments
of most Universities have Architects in their
employment. Alternatively,
you may have your questionnaire in a link form to
share on our various
architectural platforms for them to answer at will.

Thank you.

On 2024-05-06 12:16, Williams Miller Appau wrote:
> Thank you for your response. However, the
purpose of my request is to
> get gatekeepers acceptance to conduct a survey
with Ghana Institute of
> Architects members. The university's facilities
management unit forms
> part of the study, but there are technical questions
that can be
> answered by Architects. Please, see attached





BOLGATANGA TECHNICAL UNIVERSITY

(Office of the Registrar)

Our Ref: BTU/GA/02

Your Ref:



Post Office Box 767
Bolgatanga
U.E.R. – Ghana

3rd June, 2024.

APPAU WILLIAMS MILLER
DURBAN UNIVERSITY OF TECHNOLOGY
FACULTY OF ENGINEERING AND THE BUILT
ENVIRONMENT.
SOUTH AFRICA

Dear Sir,

RE: LETTER OF REQUEST TO CONDUCT RESEARCH

Your request for permission to interact with students and also access the University's hall of residence to collect data for your research work has been approved. You are required to treat all information received from the University as confidential.

Do not hesitate to contact us if need be.

Thank you.

Yours faithfully,

HANNAH BAGRABA
DIRECTOR OF GENERAL SERVICES
FOR: REGISTRAR

Cc: Vice-Chancellor, Pro VC, Registrar, Dean of Students, Director (AA), Sumbrungu Hall Tutor, Ajene Hall Tutor.



**SIMON DIEDONG DOMBO UNIVERSITY OF BUSINESS
AND INTEGRATED DEVELOPMENT STUDIES (UBIDS)**

DIRECTORATE OF WORKS AND MUNICIPAL SERVICES

Telephone: +233 (0) 39 209 7256 +233(0) 39 209 7257 Email: info@ubids.edu.gh Website: ubids.edu.gh
Box: P.O.Box WA64, Wa, Upper West Region-Ghana. SDD-UBIDS Digital Address: XW-1147-8901, Bamahu-Wa

Mr. Appau Miller

18th April, 2024.

PHD. Candidate

Dept. Construction Management

Durban University of Technology

Durban.

Dear sir,

**RE: LETTER OF REQUEST TO CONDUCT RESEARCH / PARTICIPATE IN PILOT
TESTING**

I write to acknowledge receipt of your letter on the above subject. I have no objections and provide my consent for the research project proposed and to conduct the study and pilot testing at Simon Diedong Dombo University of Business and Integrated Development Studies (SDD-UBIDS).

As the Director of Works at SDD-UBIDS, I believe the research findings will impact positively the use of energy and promote sustainability in the energy efficiency of the University. The potential impact of this research on optimizing energy usage in SDD-UBIDS systems will enhance resource efficiency across our operations.

In granting consent for this research, I trust that you will adhere to all ethical standards and regulatory requirements, and the rules and regulations of the University throughout your engagement to ensure a successful study.

Thank you

Yours Faithfully,

Ing. Reginald Assibey-Ankrah

(Director, DWMS)



UNIVERSITY OF EDUCATION, WINNEBA
OFFICE OF THE REGISTRAR

P. O. Box 25, Winneba, Ghana
+233 (03323) 22269

registrar@uew.edu.gh
+233 (03323) 22269

R.252/RFU/80

23th May, 2024

Mr. Williams Miller Appau
Department of Construction Management and
Quantity Surveying
Durban University of Technology
South Africa

Dear Mr. Appau,

RE: LETTER OF REQUEST TO CONDUCT RESEARCH

Your letter received through email on the above subject refers.

I am directed by the Acting Registrar of the University of Education, Winneba to inform you that the following senior members of the University, as per your request, have expressed their willingness to assist you in your research on the topic: *"Framework for Evaluation of Energy Sustainability in Changing University Students' Housing in Ghana"*.

- Dean of Student Affairs
- Estate Officer
- Hall Managers (Ghartey Hall, Simpa Hall, Kwegyir Aggrey Hall and University Hall)

We wish you a success in your research.

Thank you.

Yours sincerely,

ABA EWUABA BOTWE (MRS.)
FOR: AG. REGISTRAR

cc: Dean, Student Affairs
Estate Officer
All Hall Managers





UNIVERSITY OF ENERGY AND NATURAL RESOURCES, SUNYANI
OFFICE OF THE REGISTRAR
HUMAN RESOURCES DIVISION
P.O. Box 214, Sunyani | www.sunr.edu.gh | +233 (0) 242 542 408 | hr@sunr.edu.gh

May 15, 2024

Our Ref: 74 SF.1

TO WHOM IT MAY CONCERN

RE: LETTER OF REQUEST TO CONDUCT RESEARCH

This is to introduce to you Mr. Appau Williams Miller (student number 22384333), a PhD student in the Construction Management and Quality Surveying Department at Durban University of Technology, Durban, South Africa. He has been granted permission to conduct his research with the University of Energy and Natural Resources, Sunyani.

Mr. Appau is required to complete a research on the topic: **"Framework for Evaluation of Energy Sustainability in Changing University Students' Housing in Ghana"**. This research requires interacting with students and accessing university hall residence to collect data on student housing design requirements towards sustainability, energy usage, drivers and barriers of adopting to sustainable student housing, and students' behavioral attitude towards energy consumption.

We would therefore be grateful for any courtesies and support extended to him during his research.

Thank you.

HATFORD ANNE
DEPUTY REGISTRAR/HEAD
HUMAN RESOURCES DIVISION
FOR: REGISTRAR

cc: Registrar
File



Department of
Engineering and
Environment
Durban University of Technology
51 Level 5, Room 505/506 Steve Biko
Campus,
Durban, 4001
P.O. Box 1184, Durban, South Africa, 4000
Tel: (031) 259 2143
Fax: (031) 259 281

The Registrar
Energy and Renewable Natural Resources
Sunyani, Ghana

Dear Sir/Madam,

LETTER OF REQUEST TO CONDUCT RESEARCH

Please, I would be grateful if you could grant me the opportunity to conduct my studies in your high esteemed Office. I am Mr. Appau Williams Miller (student number 22384333), a Ph.D. student in the Construction Management and Quantity Surveying Department at Durban University of Technology, Durban, South Africa. I am conducting research titled: **"Framework for evaluation of energy sustainability in changing university students' housing in Ghana under Dr. Anugwo Iruka C principal supervisor.** The research requires the interaction with students and access to university hall of residence to collect data on student housing design requirements towards sustainability, energy usage, drivers and barriers of adopting to sustainable student housing, and students' behavioural attitude towards energy consumption. I have therefore identified the senior members at the Department of Renewable Energy Engineering as a potential source of primary information for my study. There are no known risks, current or anticipated, to any participant in this research, and all information received will be treated with the utmost confidentiality. I kindly request that you provide me with a gatekeeper's approval letter for ethical purposes. With regards to any queries, please do not hesitate to contact 22384333@dut4life.ac.za and irukaA@dut.ac.za

**DEPARTMENT OF CONSTRUCTION STUDIES,
FACULTY OF PLANNING AND LAND MANAGEMENT (FPLM)
SIMON DIEDONG DOMBO UNIVERSITY OF BUSINESS AND
INTEGRATED DEVELOPMENT STUDIES (SDD-UBIDS)**
Post Office Box UPW 3, Wa, Upper West Region



FROM: The Head, Department of Construction Studies

TO: Mr. William Appau Miller

DATE: April 15, 2024

**SUBJECT: PERMISSION TO PILOT RESEARCH TOOLS IN THE DEPARTMENT OF
CONSTRUCTION STUDIES**

Following your request on the above subject, I write to grant you the permission to pilot your PhD Research tools in the Department of Construction Studies. The Senior Members in the Department are available to offer you the necessary support in this regard.
Best regards.

Dr. Darius T. Mwingyine

Cc:
Senior Members, DCS



Kwame Nkrumah
University of Science
and Technology, Kumasi

KNUST/RO/GEN

OFFICE OF THE REGISTRAR

April 18, 2024

Mr. Williams Miller Appau
Department of Construction Management
And Quantity Surveying
Faculty of Engineering and the Built Environment
Durban University of Technology
PO.BOX 1334, Durban
South Africa.

Dear Appau,

RE: LETTER OF REQUEST TO CONDUCT RESEARCH

This is to acknowledge receipt of yours on the above seeking permission to undertake research.

On behalf of the Registrar, I write to inform you that approval has been granted to enable you to collect data for the research on the topic: **"Framework for the Evaluation of Energy Sustainability in Changing University Students' Housing in Ghana"**.

By a copy of this letter, Students and Officers concerned are respectfully requested to provide the necessary assistance and cooperation for the purpose.

Sincerely Yours,


Evis Twum-Barimah (REV)
JUNIOR ASSISTANT REGISTRAR
For: REGISTRAR

cc: Vice - Chancellor
Pro Vice – Chancellor
Director of Works and Physical Development
Director, Students Affairs
Deputy Registrar, Academic Affairs
Hall Masters/Warden, Halls of Residence



**TAMALE
TECHNICAL
UNIVERSITY**

P.O. Box 3 E/R, Tamale, Ghana
233-03720-22771, 23850
233-03720-23849, 22552
info@tatu.edu.gh
www.tatu.edu.gh

Our Ref:.....TaTU/41.SF.3.....

Your Ref:.....

Date: 27th May, 2024

Mr. Appau Williams Miller
Dept. of Construction Management & Quantity Surveying
Dutut Durban University of Technology
Durban South Africa
Tel: +233(0)245452406

Re: Letter of Request to Conduct PhD Research – Appau Williams Miller

Your letter on the above subject is referred.

This is to inform you that approval has been given to your request to carry out an academic research with the University students and the Directorate of Works and Physical Development.

The Dean of Students Affairs and the Director of Works and Physical Development are your contact persons to assist you in the conduct of your research.

However, the University will not be associated with any cost or expense resulting from the research.

We wish you all the best in this regard.

Thank you very much.

Yours faithfully,

**ALHAJI YAKUBU IDDRISU
(REGISTRAR)**

CC: Vice Chancellor
Pro Vice Chancellor
Dean of Students Affairs
Director of Works & Physical Development
Deputy Registrar, HRD

UNIVERSITY FOR DEVELOPMENT STUDIES
(Office of the Dean of Student Affairs)
Central Administration

Website: www.uds.edu.gh



P. O. Box TL 1350
Tamale, Ghana

May 30, 2024

Our Ref:

Mr. Appau Williams Miller
Department of Construction Management and Quantity Surveying
Faculty of Engineering and the Built Environment
S3 Level 2, Steve Biko Campus
Durban University of Technology (DUT)
Durban, KwaZulu-Natal, South Africa

Dear Sir,

RE: LETTER OF REQUEST TO CONDUCT RESEARCH

I refer to your letter on the subject matter and write to convey approval for you to conduct your research in the University for Development Studies on the topic: *“Framework for Evaluation of Energy Sustainability in Changing University Students’ Housing in Ghana”*.

You are advised to adhere to all ethical standards in the conduct of your research. We are hopeful the research will make significant contributions to your academic progress. Have our best wishes.

Thank you.

Umar Haruna (PhD)
(Vice Dean of Students, Tamale Campus)
for: Dean of Students’ Affairs

cc: Hall Master, Tamale Campus
Senior Hall Tutor, Sagnarigu Hall
Senior Hall Assistant, Sagnarigu Hall
Yaa Naa Hall Manager

TELEPHONE: 233-42-32480-3 Ext. 227
FAX 233-42-32484/5
E-MAIL: tds@ucc.edu.gh
WEBSITE: www.ucc.edu.gh



3rd June, 2024

INTRODUCTORY LETTER: MR. APPAU WILLIAMS MILLER

Thank you.,

SENIOR ASSISTANT REGISTRAR
For: **REGISTRAR**

Distribution:
The Dean of Students, UCC
The Director, Directorate of Physical Dev't and Estate Management, UCC

cc: Registrar
Director, DHR
Mr. Appau Williams Miller (0245452406)

KUMASI TECHNICAL UNIVERSITY

OFFICE OF THE REGISTRAR
Tel. No: 0322 022 388
Email: registrar@kstu.edu.gh
Website: www.kstu.edu.gh



P. O. Box KS 854
Kumasi - Ashanti,
Ghana, West Africa

Our Ref: KsTU/ADM/456

05/06/2024

Mr Appau Williams Miller
Department of Construction Management and Quantity Surveying
Faculty of Engineering and the Built Environment
S3 Level 2, Steve Biko Campus
Durban University of Technology
Durban, Kwazulu-Natal
South Africa

22384333@dut4life.ac.za
irukaA@dut.ac.za

Dear Mr. Miller,

Re: Letter of Request to Conduct Research

Your letter on the subject above refers.

We are glad to inform you that permission has been granted for you to collect data from our University for your PhD research work on the topic 'Framework for the evaluation of energy sustainability in changing university students' housing in Ghana'.

You may contact the undersigned via email address: general.admin@kstu.edu.gh for further assistance regarding your request.

By a copy of this letter, the Dean of Students and the Estate Officer are kindly requested to assist you in the collection of the data.

Thank you.

Yours sincerely,

Jenkins A. Asaah (PhD)
Deputy Registrar (Gen. Admin)
FOR: REGISTRAR

Cc: Vice-Chancellor
Dean of Students
Estate Officer

ENERGY COMMISSION

Ghana Airways Avenue, Airport Residential Area (behind Alliance Française)

Private Mail Bag
Ministries Post Office
Accra - Ghana

Tel: 0302 813756/7
Fax: 0302 813764
IDD Code: (233-302)
E-mail: info@energycom.gov.gh
Website: <http://www.energycom.gov.gh>

Our Ref.: EC/INTORG/01/06/2024

20th June 2024



Mr. Appau Williams Miller (student number 22384333)
Faculty of Engineering & The Built Environment
Department of Construction Management and Quantity Surveying
DUT Durban University of Technology
53 Level 2, Room B53 404 Steve Biko Campus
Durban, 4001
P. O. Box 1334
Durban, South Africa, 4000

Dear Mr. Appau Williams Miller,

Subject: Re - Letter of Request to Conduct Research

We have received your request regarding the Ph.D. research titled "Framework for Evaluation of Energy Sustainability in Changing University Student's Housing in Ghana.

While we are eager to support academic research, we believe the researcher would benefit significantly from working closely with universities and tertiary institutions in Ghana where there are existing student housing facilities. These institutions can provide invaluable insights and information regarding the design of student housing, as well as data on students' energy use behavior.

The Energy Commission can provide data on energy consumption patterns and energy efficiency measures.

Please let us know if there are specific data requirements or further assistance needed from our side.

We look forward to potential future collaborations and wish you success in your research.

Best regards,

Ing. Oscar Amonoo-Aweizer
Executive Secretary

Cc: Dr. Anugwo Iruka C, Principal Supervisor
Director, Energy Efficiency & Energy Regulation



**TAKORADI
TECHNICAL
UNIVERSITY**

**CENTRE FOR RESEARCH,
INNOVATION AND DEVELOPMENT**

P. O. BOX 256, TAKORADI - GHANA
Website: www.ttu.edu.gh Email: crd@ttu.edu.gh

Ref. No. TTU/ERC/24/001

July 15, 2024

Mr. Williams Miller Appau
C/O P. O. Box 100
CP Kasoa, Central Region
Ghana

Dear Sir

LETTER OF APPROVAL

The Ethics Review Committee of the University has considered the ethical merit of your proposed research project titled **"Framework for Evaluation of Energy Sustainability in Evolving University Students' Housing in Ghana"** and has approved it.

The data collected should be used for the approved purpose only. Prior permission should be sought from the committee if there is the need to vary the research project or the primary purpose for which the data would be collected. You are expected not to release the data to any other person or researcher for the same or any other purpose without prior permission from the Committee.

The committee respectfully request you to abide by all the relevant ethical principles required by your research.

Kindly furnish the Committee with a summary of the key research findings upon completion of the research.

Thank you Sir, for your application.

Yours faithfully

Prof. Emmanuel M. Baah
Chairman
Ethics Review Committee
Takoradi Technical University

