

A roadmap for net-zero energy buildings in emerging economies: a study of residential new-buildings in Nigeria

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A Roadmap for Net-Zero Energy Buildings in Emerging Economies: A study of Residential New-Buildings in Nigeria.

By

Chieloka Emmanuel

(B.Sc., M.Sc.)

Thesis submitted in partial fulfilment for the Award of Doctor of Philosophy

At The

University of Wolverhampton, United Kingdom

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Finally, to those who contributed directly or indirectly towards the development of this thesis, thank you.

Thank you all for being a part of this remarkable journey.

Chieloka

Declaration

I, Chieloka Emmanuel, hereby declare that this thesis is my original work.

I affirm that:

The work contained in this thesis has not previously been submitted for the award of a degree or any other academic qualification at the University of Wolverhampton or at any other institution.

All sources, such as journal articles and other materials used in this thesis, have been cited and referenced appropriately.

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Approval

This thesis titled A Roadmap for Net-Zero Energy Buildings in Emerging Economy: A study of Residential New-Buildings in Nigeria submitted by Chieloka Emmanuel in partial fulfilment of the requirements for the degree of Doctor of Philosophy, has been thoroughly reviewed by the undersigned and recommended to the Doctoral College, University of Wolverhampton, for acceptance.

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Table of Contents

Acknowledgement.....	ii
Declaration.....	iii
Approval.....	iv
List of Figures	viii
List of Tables	x
Abbreviations and Acronyms	x
Abstract	xiii
CHAPTER 1: INTRODUCTION.....	1
1.1 Chapter Introduction.....	1
1.2 Background of Study	1
1.3 Research Problem	2
1.4 Research Justification.....	3
1.5 Research Gaps.....	8
1.6 Research Questions.....	9
1.7 Research Aim & Objectives	10
1.8 Contribution to Knowledge.....	10
1.9 Scope and Limits of Study.....	11
1.10 Benefits and Beneficiaries	11
1.11 Methodology.....	12
1.12 Thesis Structure.....	13
1.13. Research Development	15
1.14. Chapter Summary.....	15
CHAPTER 2: LITERATURE REVIEW	16
2.1 Chapter Introduction.....	16

2.2 The Concept of Net-Zero Energy Building (NZEB).	16
2.3 The Concept of Emerging Economies.....	18
2.4 Decarbonisation Status for Buildings and Progress since the Paris Agreement – A 2022 Global Review.....	19
2.5 NZEB in Emerging Economies: An Overview.....	22
2.5.1 The Significance of NZEB in Emerging Economy.....	22
2.5.2 Status of NZEB in Emerging Economies.....	22
2.5.3 Barriers to NZEB market penetration in Emerging Economies.....	23
2.6 The United Nation’s Sustainable Development Goals (SDGs) 7, 11 and 13.....	24
2.7 The Impact of COVID -19 Pandemic on the 2050 target.	29
2.8 Green Building Policies & Regulations: Global Focus	30
2.8.1 Building Energy Codes	30
2.8.2 Green Building Certification	32
2.9 Energy Efficiency in Buildings: A Global Perspective	33
2.9.1 Key Factors Affecting Energy Demands in Buildings.....	35
2.10 The Study Context: Nigeria.....	37
2.10.1 Overview of Nigeria	37
2.10.2 Nigeria’s Response to Climate Change	40
2.10.3 Nigeria’s Key Climate Change Policies	43
2.10.4 Nigeria’s Global and Regional Partnerships on Climate Change.....	45
2.10.5 The Nigerian Energy Sector	49
2.10.6 Benefits of NZEBs: Nigeria’s Perspective	56
2.10.7 Key Barriers & Drivers to achieving NZEB in Nigeria.....	58
2.11 An Overview of Green Building Standards: BREEAM, LEED, Passivhaus, EDGE and NBEEC.....	62
2.11.1 BREEAM.....	62
2.11.2 LEED.....	64
2.11.3 Passivhaus (Passive House Standard)	68
2.11.4 EDGE.....	70

2.11.5 Nigeran Building Energy Efficiency Code (NBEEC).....	76
2.12 Technological Solutions / Interventions for achieving NZEBs in Nigeria.....	80
2.13 Case Study.....	83
2.13.1 CASE STUDY 1 – Colombia: The path to Net-Zero.	83
2.13.2 CASE STUDY 2 – Costa Rica: The path to Net-Zero	87
2.14 Chapter Summary.....	92
CHAPTER 3: RESEARCH METHODOLOGY	93
3.1 Chapter Introduction.....	93
3.2 Research Paradigm.....	93
3.2.1 Research Philosophy.....	94
3.2.2 Research Approach.....	99
3.2.3 Research Strategy.....	101
3.3.4 Choice of Method.....	102
3.2.5 Time Horizon	108
3.2.6 Data Collection and Analysis.....	108
3.3 Ethical Consideration.....	114
3.4 Chapter Summary.....	115
CHAPTER 4: RESULTS AND FINDINGS	116
4.1. Chapter Introduction.....	116
4.2. Survey Questionnaire	116
4.3 Expert Interview	136
4.4 Chapter Summary.....	144
CHAPTER 5: DISCUSSION AND PROPOSAL	145
5.1 Chapter Introduction.....	145
5.2 The current state of NZEBs in Nigeria.....	145
5.3 Key Barriers to achieving NZEB in Nigeria	147
5.4 Key Drivers of NZEB in Nigeria.....	150
5.5 Proposed Strategic Roadmap	151

5.6 Chapter Summary.....	156
CHAPTER 6: CONCLUSION, RECOMMENDATION, AND FUTURE WORKS	157
6.1 Chapter Introduction.....	157
6.2 Summary	157
6.3 Contribution to Knowledge	160
6.4 Research limitation.....	162
6.5 Recommendation	163
6.6 Future Research	163
6.7 Conclusion and Closing Remarks.....	164
Reference.....	166
APPENDICES	193

List of Figures

<i>Figure 1.1: Thesis Structure – Introduction. Source: Author</i>	<i>Error! Bookmark not defined.</i>
<i>Figure 1.2: Total Energy-Resource Consumption in 2012. Source: NESP</i>	5
<i>Figure 1.3: Biofuels and Waste Consumption by Sector in 2012. Source: NESP</i>	5
<i>Figure 1.4: Total Energy Consumption by Economic Sectors. Source: (NESP, 2012)</i>	6
<i>Figure 1.5: Total Electricity Consumption by Economic Sectors. Source: (NESP,2012).....</i>	7
<i>Figure 1.6: Total Electricity Consumption by Economic Sector (1990 – 2010). Source: IEA</i>	8
<i>Figure 1.7: Green Building Topic Trend Globally. Source: Author.</i>	9
<i>Figure 1.8: Discuss on NZEB in emerging and advanced economy. Source: Author</i>	9
<i>Figure 1.9.: Research Development Process</i>	15
<i>Figure 2.1: 2021 GBCT for the Decarbonization of buildings (Hamilton et al., 2022).....</i>	20
<i>Figure 2.2: 2021 GBCT for the Decarbonisation of buildings (Hamilton et al., 2022).....</i>	21
<i>Figure 2.3: Research interaction with United Nations SDGs</i>	25
<i>Figure 2.4: 2021 GBCT for the Decarbonisation of buildings (Hamilton et al., 2022).....</i>	30
<i>Figure 2.5: Global status of building energy codes in 2021. (UNEP. 2022)</i>	31
<i>Figure 2.6: 2022 Global Building Energy Code status. (UNEP, 2022)</i>	32
<i>Figure 2.7: Global Energy Consumption by sector (IEA,2020)</i>	34
<i>Figure 2.8: Location of Nigeria on world map (World Atlas,2021).....</i>	38
<i>Figure 2.9: Nigeria’s population increase 2010 - 2020.</i>	<i>Error! Bookmark not defined.</i>
<i>Figure 2.10: Climatic Zones of Nigeria. Source: (FMPWH).....</i>	40

Figure 2.11: Total Energy Consumption by Economic Sectors (GIZ, 2012).....	50
Figure 2.12: 5 key sectors of the Nigeria’s ETP (ETP, 2021).....	51
Figure 2.13: Percentage of the Nigeria’s ETP in-scope sector emissions (ETP, 2021)	52
Figure 14: Nigeria's ETP decarbonisation strategy by sector.....	52
Figure 2.15: summary of potential benefits of NZEB adoption in Nigeria under the 3 pillars of sustainability. Source: Author.....	Error! Bookmark not defined.
Figure 2.16: EDGE certified buildings around the world. (MITSIDI PROJECTOS, 2022)	72
Figure 2.17: EDGE Annual Global Certification (MITSIDI PROJECTOS, 2022).	72
Figure 2.18: Three (3) stages of EDGE Certification (MITSIDI PROJECTOS, 2022)	73
Figure 2.19: Countries with the most EDGE Certified Buildings (MITSIDI PROJECTOS, 2022)	74
Figure 2.20: Countries with the most EDGE Advanced Buildings (MITSIDI PROJECTOS, 2022).....	74
Figure 2.21: Building Energy Label – Prescriptive Based (BEEC,2017).....	78
Figure 2.22: Building Energy Label – Performance Based (BEEC, 2017)	79
Figure 2.23: BEEC Energy Allowance (BEEC, 2017).....	80
Figure 3.1: The Research Onion (Saunders et al., 2016)	94
Figure 3.2: Flow chart of data collection from a population.....	Error! Bookmark not defined.
Table 15: Sampling Method. Source: Author	110
Figure 3.3: Raosoft Sample Size Calculator.....	111
Figure 4.1: Profession of the respondents.....	116
Figure 4.2: Sector of the respondents	117
Figure 4.3: Years of industry experience of respondents.....	118
Figure 4.4: Respondents Familiarity of EE	119
Figure 4.6: Number of EE building projects respondents have been involved in	120
Figure 4.7: Extent of respondent’s involvement with NBEEC interventions	121
Figure 4.8: Extent of respondent’s usage of EE strategy in new builds and retrofits	122
Figure 4.9: Extent of respondent’s usage of EE strategy in various building types.....	123
Figure 4.10: Respondents familiarity with key energy standards.....	125
Figure 4.11: Energy standards adopted by respondents or their organisation.....	126
Figure 4.12: Ranking of key barriers in their order of importance.....	127
Figure 4.13: Ranking of key technical/technological barriers in their order of importance.	130
Figure 4.14: Ranking of key institutional barriers in their order of importance.	131
Figure 4.15: Ranking of key economic/financial barriers in their order of importance.	132
Figure 4.16: Ranking of key social/cultural barriers in their order of importance.	133
Figure 4.17: Ranking the key drivers of NZEB in Nigeria in their order of importance.	134
Figure 4.18: Colombia’s path to Net-Zero.....	86
Figure 4.19: Countries with the most EDGE Certified Buildings (MITSIDI PROJECTOS, 2022)	87
Figure 5.1: Chapter Structure - Discussion and Proposal. Source: Author.....	Error! Bookmark not defined.
Figure 5.2: Identification process of NZEB status quo (Source Author).....	145

Figure 5.3: Identification process of the key barriers to achieving NZEB in Nigeria	147
Figure 5.4: Identification process of key drivers of NZEB in Nigeria	150

List of Tables

Table 1: United Nations SDG 7 and 2030 targets (United Nations, 2021)	Error! Bookmark not defined.
Table 2: United Nations SDG 11 and 2030 targets (United Nations, 2021)	Error! Bookmark not defined.
Table 3: United Nations SDG 13 and 2030 targets (United Nations, 2021)	Error! Bookmark not defined.
Table 4: Geographical areas and their corresponding green building rating systems. (UNEP, 2022)	Error! Bookmark not defined.
Table 5: A summary of the United Nations Framework Convention on Climate Change (UNFCCC).....	46
Table 6: A summary of The Paris Agreement.....	46
Table 7: An overview of Nigeria's engagement with the AUC on climate change	Error! Bookmark not defined.
Table 8: Nigeria's ETP decarbonisation strategy by sector	52
Table 9: Potential benefits of NZEB adoption in Nigeria.	Error! Bookmark not defined.
Table 10: BREEAM Rating System	63
Table 11: LEED Rating System	Error! Bookmark not defined.
Table 12: Types of Mixed Methods Research Approach. Source: Author	104
Table 13: Qualitative, Quantitative, and Mixed Methods Approaches (Creswell and Creswell, 2018,p.18)	104
Table 14: Comparison Between Qualitative and Quantitative Research Method. Source: Author.....	108
Table 15: Sampling Method. Source: Author	110
Table 16: Building professionals and their years of experience	118
Table 17: Extent of Energy efficiency application on building categories	124
Table 18: ANOVA (Two-Factor) Test Result	128
Table 19: Costa Rica's comprehensive roadmap to NZEB.....	90
Table 20: Development of the expert interview analysis	137
Table 21: Proposed Strategic Roadmap.....	152
Table 22: Addressing the research question.	160
Table 23: Study recommendation	Error! Bookmark not defined.

Abbreviations and Acronyms

AFDB – African Development Bank

ANOVA – Analysis of Variance

CDM – Clean Development Mechanism

CO₂ – Carbon Dioxide

CPD – Continuing Professional Development

ECOWAS – The Economic Community of West African States

EDGE – Excellence in Design for Greater Efficiencies

ETP – Energy Transition Plan

FIT - Feed-in Tariff

GBCN – Green Building Council of Nigeria

GHG – Greenhouse Gas

GIZ – The Deutsche Gesellschaft für Internationale Zusammenarbeit

IEA – International Energy Agency

IMCCC – Inter-Ministerial Committee on Climate Change

IPCC - Intergovernmental Panel on Climate Change

IPHA - International Passive House Association

NACOP – The Nigeria National Council of Power

NASPA-CCN – National Adaptation Strategy and Plan of Action on Climate Change

NBEEC - Nigerian Building Energy Efficiency Code

NDC -Nationally Determined Contribution

NEE – Newly Emerging Economies

NERC - Nigerian Electricity Regulatory Commission

NERC - Nigerian Electricity Regulatory Commission

NESP – Nigerian Energy Support Programme

NREEEP - National Renewable Energy and Energy Efficiency Policy

NZC – Net Zero Carbon

NZEB – Net-Zero Energy Building

OECD – The Organisation for Economic Cooperation and Development

PPP – Public-private Partnerships

REA - Rural Electrification Agency

REA - Rural Electrification Agency

REF - Renewable Energy Fund

REMP - Renewable Energy Master Plan

SCCDs – State Climate Change Departments

SDG – Sustainable Development Goals

UN – United Nations

UNCCC - United Nations Climate Change Conference

UNEP – United Nations Environmental Programme

WAPP – West African Power Pool

Abstract

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The building industry is widely believed to be a major contributor to global greenhouse gas (GHG) emissions and consequently, climate change worldwide. Buildings contribute approximately 40% of global energy consumption and over 30% of total CO₂ emissions. Over the past three decades, there has been progressive research interest in low-energy buildings in emerging economies. However, the issue of Net-Zero Energy Buildings (NZEBs) is less discussed and less represented in literature in the context of emerging economies. The aim of this research is to develop a strategic roadmap to achieve NZEBs in Nigeria within the residential sector.

Data was obtained using survey questionnaires, and expert interviews. The quantitative data was analysed using descriptive statistics and Inferential statistics, while the qualitative data was analysed using thematic analysis. Based on the research findings, a strategic roadmap with timelines and milestones was developed to achieve NZEBs within the residential sector in Nigeria. The nature of this roadmap involves policy creation and implementation, regulatory frameworks, investments, and partnerships.

Research findings indicate potential future research on lifecycle analysis of buildings and circular economy in Nigeria, NZEB retrofit, and NZEB technological Interventions.

This study makes novel theoretical contributions by addressing the issue, context, and level of analysis gap in literature on NZEBs in emerging economies. From a practical standpoint, it provides researchers, industry professionals, policymakers, funding bodies, and the third sector with a strategic roadmap with short-term, medium-term, and long-term strategies tailored to Nigeria's development needs and priorities. The implementation of the proposed roadmap can catalyse the scalable adoption of net-zero energy residential buildings, thereby reducing Nigeria's carbon footprint and supporting its sustainable development goals.

Keywords: NZEB, net-zero emissions, energy efficiency, decarbonisation, low-energy building, emerging economies.

CHAPTER 1: INTRODUCTION

1.1 Chapter Introduction

This chapter gives insights into the focus and expectations of this research. The chapter sets the stage for subsequent chapters. It presents the research background, the research problem, the research question, the research aim and objectives, the contribution to knowledge, and the research scope and limits of study. Additionally, it discusses the benefits and beneficiaries of the research, the methodology to be adopted, and the thesis structure.

1.2 Background of Study

The global community has reached a decisive decade (decade of action) for international efforts to tackle climate change. Climate change is an existential threat that requires urgent attention to move towards a low-carbon world (Figueres, 2020; Goncalves, 2020; United Nations, 2017). The warnings by the Intergovernmental Panel on Climate Change (IPCC) for years on the impact of climate change are now our reality. The rapid change in the climate due to anthropogenic activities fundamentally associated with energy consumption and GHG emissions has been well documented in literature. According to the Secretary-General of the United Nations, Antonio Guterres, we have seen record heat waves, wildfires, floods, droughts, etc., and never has it been so clear that a strategic approach is needed to tackle the climate crisis and achieve a sustainable environment (Goncalves, 2020; PEEB, 2019). Recent years have seen progressive efforts towards tackling climate change, however, to achieve The Paris Agreement goal, which was set up to tackle climate change, more must be done. The goal is to keep the global temperature well below 2 degrees Celsius and to pursue efforts to further limit the temperature to 1.5 degrees to achieve a net zero emission globally by 2050, as agreed in The Paris Agreement (United Nations, 2020; UNEP, 2017). If there is to be a fighting chance of reaching net-zero by 2050 and limiting the rise in global temperatures to 1.5 °C, the gap between rhetoric and action needs to be significantly bridged. To achieve this target, all sectors of the economy as well as the governments of nations must adopt a net-zero strategy. The IEA estimated that the building sector would need to realise an annual average energy intensity reduction of 4-5 percent per year between now and 2050 if the 2050 net zero target is to be achieved (Feng, *et al.*, 2019a; Legnér and Leijonhufvud, 2019). With about 40% of global energy consumption and over 30% of all CO₂ emissions, the building sector is no doubt a major contributor to climate change in comparison to other sectors (IEA, 2011). Buildings generate more GHG pollution, consume more energy, and waste more natural resources when compared to other sectors (Li, Ng and Skitmore, 2017; Akande, Oluwafemi K., Fabiyi and Mark, 2015; Cao, Dai and Liu, 2016a; Fernandez, 2013). A

2022 Buildings Global Status Report by the United Nations Environment Programme (UNEP) shows the sector on a global scale is not making the much-needed changes required to achieve the 2050 energy target, particularly in emerging economies where the bulk of the new housing stock in the coming decades will reside (Goncalves, 2020). Emerging economies are a critical partner in the NZEB ambition; therefore, the decarbonisation of the building sector in emerging economies by 2050 is critical.

The focus of this study is residential new-builds in an emerging economy and is hinged to United Nations Sustainable Development Goal 7 (affordable and clean energy), 11 (sustainable cities and communities), and 13 (climate action).

This section gave an insight into the study from a global perspective, down to the building sector and emerging economies. In the following section, the research problem will be discussed.

1.3 Research Problem

Rapid urbanisation is presenting emerging economies with a number of challenges, including rising pollution and energy demand in urban areas (World Bank, 2015). The World Bank projects that energy consumption will increase by 37% by 2035, with emergent economies accounting for 96% of this growth (Nematchoua, *et al.*, 2019; Lin, Jan and Liao, 2017; Cao, Dai and Liu, 2016a). By 2050, the population of emerging economies will have increased by 100 percent, making them among the nation's most severely impacted by climate change (Feng, *et al.*, 2019a; Goncalves, 2020; Dodoo and Ayarkwa, 2019). However, these emerging economies only account for 20% of global clean energy investment at present (Aliyu, Modu and Tan, 2018; Abdullahi, *et al.*, 2017; United Nations, 2020). To aid in achieving the climate goal of net-zero energy by 2050, emerging markets must take more decisive action. Despite the fact that a growing number of nations have pledged to achieve net-zero carbon emissions by 2050 or shortly thereafter, it remains crucial that they devise implementation strategies for their net-zero objectives. Nigeria is a crucial global collaborator for these emerging economies (World Bank, 2015). Nigeria, with a population of over 200 million, is the most populous nation in Africa and one of the top ten most populous countries on the globe (Arup, 2016). At a projected growth rate of 3.2% per year, Nigeria's population could reach 310 million by 2035 and will be the world's third-most populous nation by 2050, behind India and China (NACOP, 2015). Goldman Sachs Investment Bank identifies Nigeria as one of the "Next Eleven" economies (Ley, 2015). It has been identified by the World Bank as one of the energy hotspots by 2050; consequently, urbanisation will increase energy demand (IEA, 2018). Only 40% of the country's population has access to the national grid, and a significant portion of them rely heavily on electric generators for their residences and places of business (Ley, 2015; Thompson and, 2018). Much of this electricity consumption in

Nigeria is attributable to the building sector, with residential buildings consuming the most compared to other building types (Abdullahi, *et al.*, 2017). According to the Energy Commission of Nigeria, residential buildings account for more than fifty percent of the country's total energy consumption (Abdullahi, *et al.*, 2017). The primary energy consumers in Nigeria's residential buildings are ventilation systems and lighting. Ley (2015) puts the estimate of household electricity consumption at 78% of the total energy consumed in the country.

In addition, Nigeria faces a severe housing deficit estimated at 17 million homes (Ley, 2015). Addressing this massive housing need through conventional building practices would result in a substantial increase in CO₂ emissions, exacerbating climate change impacts. However, this housing crisis also presents an opportunity to chart a sustainable path forward by embracing NZEB principles for new residential construction. Integrating NZEB strategies into Nigeria's efforts to meet its housing needs is crucial to avoid locking in high emissions and achieving its climate mitigation goals.

At the backdrop of this, the Nigerian government is a signatory to the Paris Agreement and has pledged to achieve its own net-zero emissions goal by 2060 (United Nations, 2017; Wei, *et al.*, 2023). However, there is no national strategy or road map for achieving this objective in buildings (Abdullahi, *et al.*, 2017; Iwuagwu and Onyegiri, 2019). This is the focus of this thesis.

This section covered the focus of this research, but why is this research being conducted? How pertinent is this research? The following section provides justification.

1.4 Research Justification

This section will focus on the justification for this study. The study's justification has been divided into three (3) themes: Why NZEB? Why Nigeria (an emerging economy)? Why new build residential buildings in Nigeria?

Issue: why NZEB?

The world must address the issue of environmental degradation caused by anthropogenic activities, in order to achieve the Net Zero Paris Agreement. Global energy consumption is on the rise, which raises concerns with problems associated with energy supply and depletion of energy resources, resulting in, among other issues, global warming, depletion of the ozone layer, high energy demand, air pollution, poor health, and low well-being (IEA, 2015). The cost of energy has steadily increased over the past decade (Aliyu, Modu and Tan, 2018; Amani, 2019). A major contributor to this is the building and construction sector (IEA, 2015). Buildings account for approximately forty percent of global energy consumption and over thirty percent of all CO₂ emissions (Feng, *et al.*, 2019a). Over 40% of the world's population presently resides in the tropics, and that number is projected to rise to 50% by 2050 (Krūmiņš and Kļaviņš, 2022). As a result, countries in the tropics and emerging

economies will have high housing demand soon to support their populations. Unsurprisingly, the projected population growth in these regions will result in an increase in energy consumption and a substantial increase in GHG emissions, with emerging economies accounting for 96% of this increase in energy consumption (Hoque and Iqbal, 2015; IPEEC, 2018; World Bank, 2018). A more robust approach to sustainability in the built environment is required to combat the climate crisis and attain a sustainable environment.

The Study Area: Why Nigeria (an emerging economy)?

Nigeria, an emerging economy projected to be the third most populous nation by 2050 after India and China, has been identified as one of the energy hotspots in 2050 by the World Bank, and the International Energy Agency (IEA) projects a 3.2% population growth rate (IEA, 2011). There is a high rate of energy demand and CO₂ emissions due to the swiftly expanding population of over 200 million people, as reported by the World Bank (Cao, Dai and Liu, 2016b). Much of this electricity consumption in Nigeria is attributable to the building sector, with residential buildings consuming the most compared to other building types (Abdullahi, *et al.*, 2017). Furthermore, Nigeria faces a housing shortage of approximately 17 million dwellings, therefore the need for a sustainable approach in addressing this housing deficit (Arup, 2017c).

Nigeria is a signatory to the Paris Agreement and has committed to achieving carbon neutrality by 2060 (IEA, 2015; UNDP, 2019). However, there is no national NZEB roadmap for residential buildings. This justifies the study area concentration of this thesis on Nigeria. This thesis outlines a distinct path to transition to net zero with timelines and milestones.

Sector: Why new build residential buildings in Nigeria?

About 27% and 17% of global energy consumption and CO₂ emissions are attributable to the residential building sector (Geissler, Osterreicher and Macharm, 2018). In Nigeria, the residential construction sector is crucial and a key player in the country's goal of achieving net-zero energy consumption. With a housing deficit of approximately 17 million units and a population growth rate of 3.2%, it is anticipated that at least 17 million residences will be constructed to close the gap (BEEC, 2017). Over the past several decades, the housing sector has consistently consumed more energy than other industries, and this trend is expected to continue in the foreseeable future (Abdullahi, *et al.*, 2017). About 85% of Nigeria's energy consumption comes from biofuels and waste, and almost 90% of this is consumed by residential buildings (Ley, 2015). Figure 1.1.

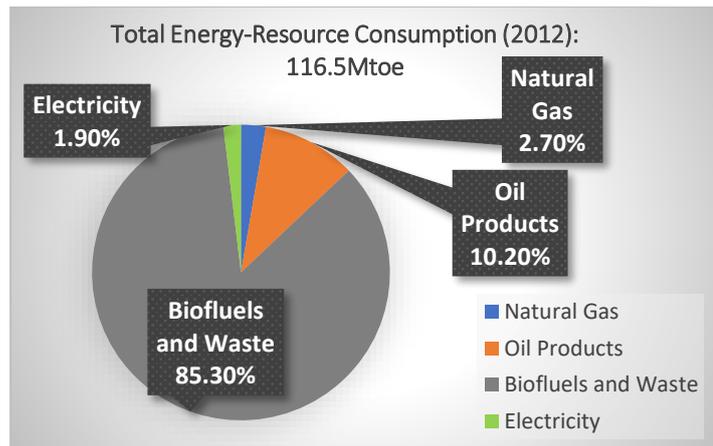


Figure 1.1: Total Energy-Resource Consumption in 2020.

(Source: NESP, 2020)

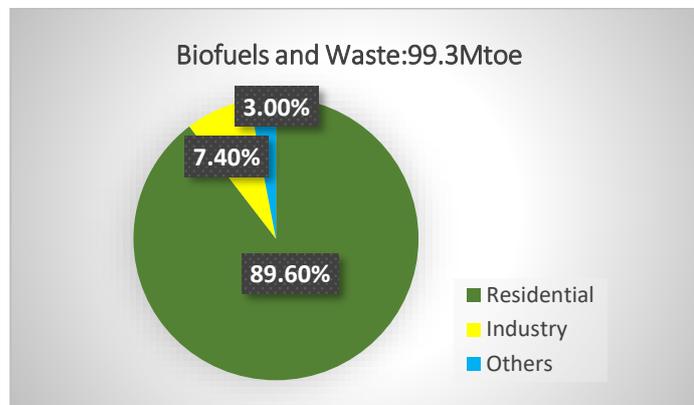


Figure 1.2: Biofuels and Waste Consumption by Sector in 2020.

(Source: NESP, 2020)

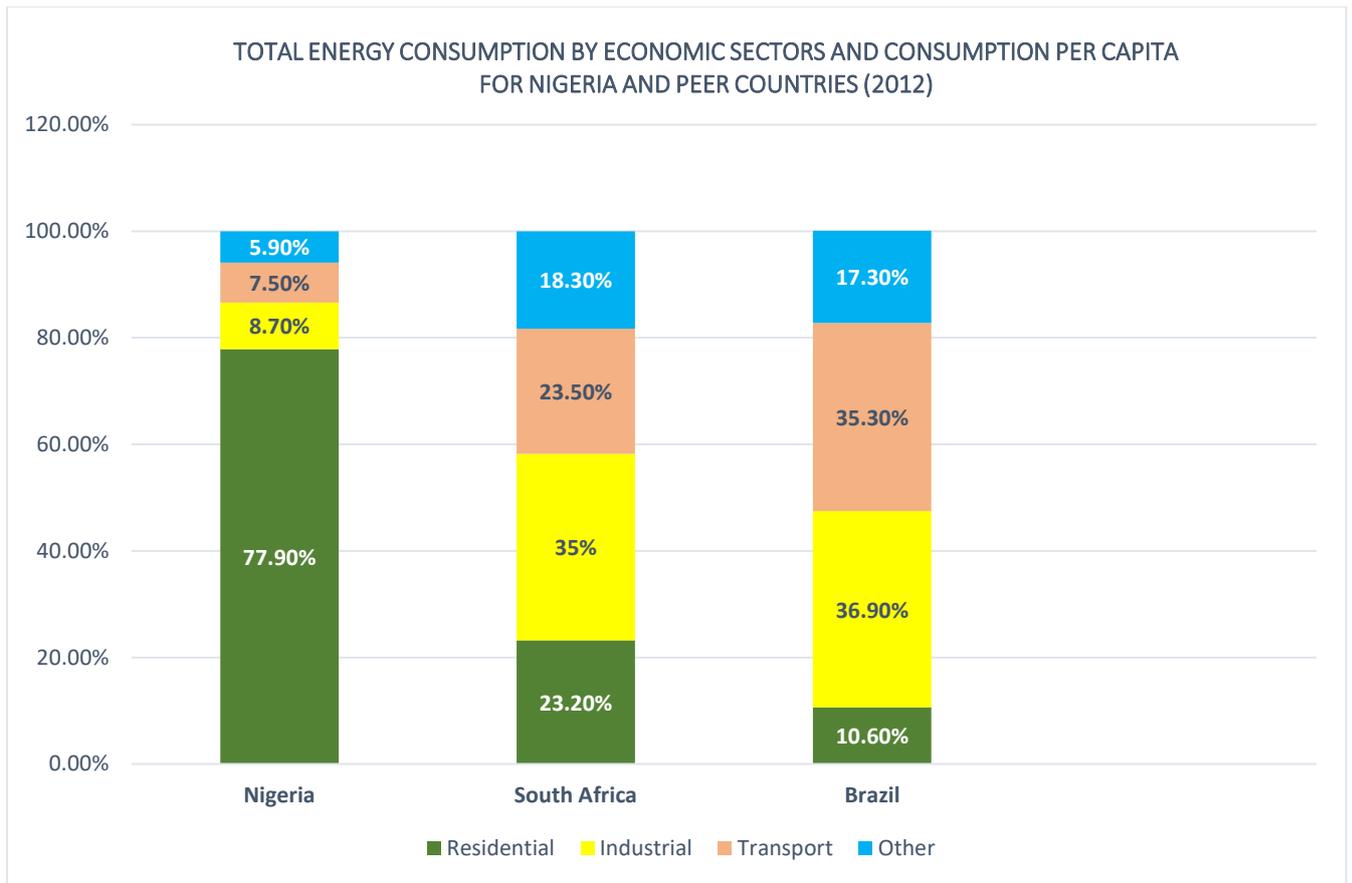


Figure 1.3: Total Energy Consumption by Economic Sectors.

(Source: NESP, 2020)

Figure 1.3 shows Nigeria’s energy consumption by economic sector compared to South Africa and Brazil. In contrast to South Africa and Brazil, Nigeria’s energy-resource is consumed significantly by the residential sector hence the focus of this thesis on residential buildings.

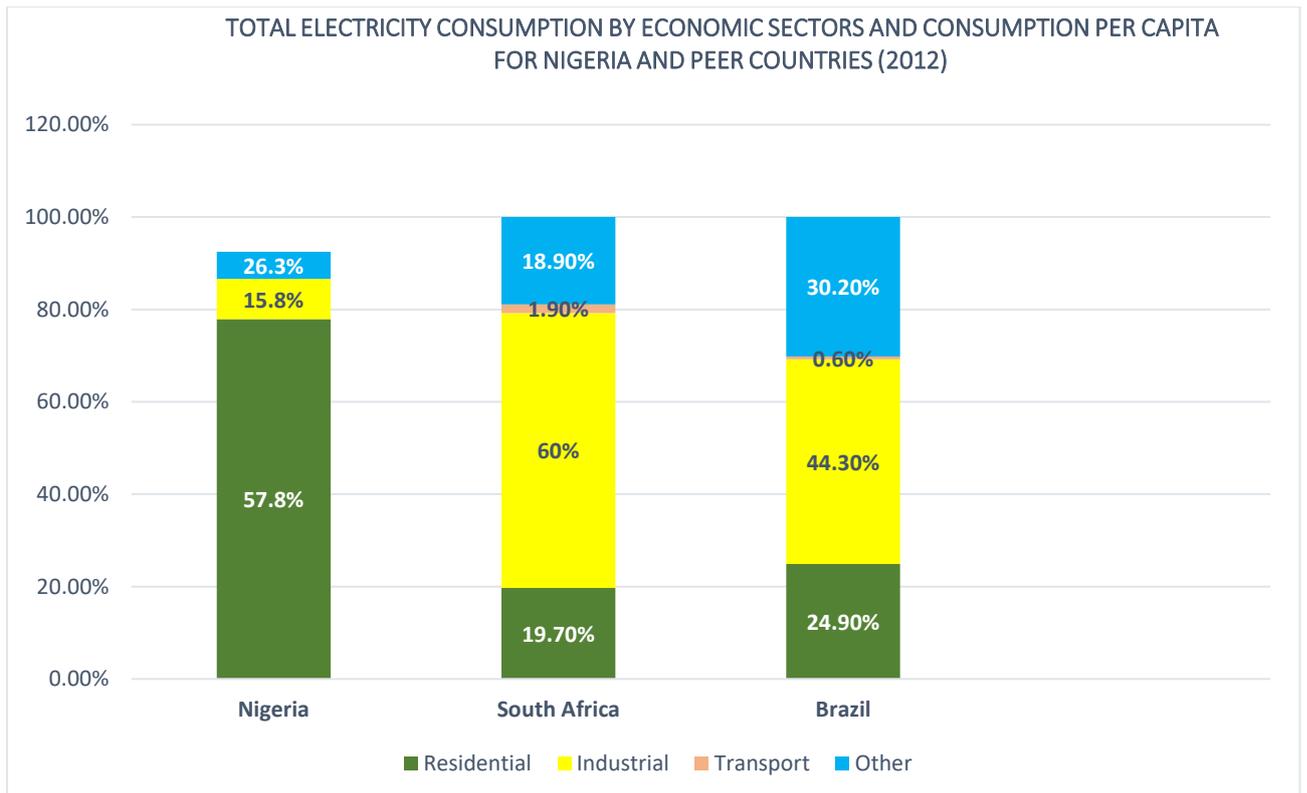


Figure 1.4: Total Electricity Consumption by Economic Sectors.

(Source: NESP, 2020)

Figure 1.4 clearly indicates that Nigeria’s residential sector consumes a significant proportion of electricity. This contrasts with South Africa and Brazil where the industrial sector consumes the most electricity.

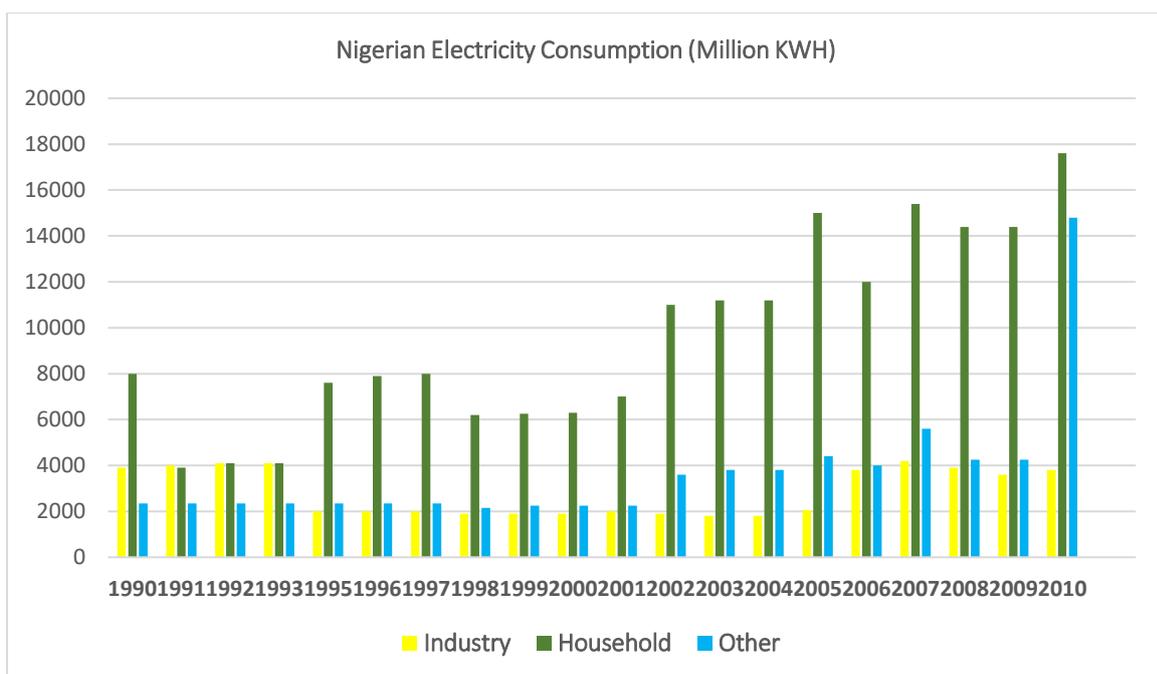


Figure 1.5: Total Electricity Consumption by Economic Sector (1990 – 2010).

(Source: IEA, 2013)

Data from IEA shows the residential sector (households) has seen a significant increase over the stated ten-year period as shown in Figure 1.5.

This section discussed three (3) justifications for why this research was conducted. The following section will discuss the research gap addressed by this thesis.

1.5 Research Gaps

A systematic review of literature exposed various gaps in knowledge. The gaps were categorised under the five (5) types of gaps: issue, theory, context, method, and level of analysis. For this research, a complex research gap was addressed. The complex gap addressed are the issue gap, context gap, and level of analysis gap. The issue being 'NZEB', the context being 'emerging economies: a study of Nigeria', and the level of analysis being 'national (macro-level)'.

Although the concept of NZEBs is relatively new and is yet to be clearly defined, studies on NZEBs have been progressive globally (Wuni, Shen and Osei-Kyei, 2019; Karlessi, *et al.*, 2017) (Figure 1.6). A significant number of these studies focused on advanced economies (Feng, *et al.*, 2019a; Deng, Wang and Dai, 2014; Allouhi, *et al.*, 2015; Fong and Lee, 2012; Good, Andresen and Hestnes, 2015). However, very little has been done on NZEBs in emerging economies, especially with respect to the development of a strategic roadmap for achieving NZEB at a national level (Wu and Skye, 2021; Feng, *et al.*, 2019a). Studies in these regions have focused mainly on energy-efficient building design strategies, low-energy buildings, renewables, indoor environmental quality (IEQ), building insulation, etc. at a micro-level (Sun, Gou and Lau, 2018) (O. Efeoma and Uduku, 2014). In Nigeria for instance, literatures such as (Ochedi and Taki, 2022; Ede, *et al.*, 2019) focused on energy-efficient building design techniques. Iwuagwu and Onyegiri (2019) analysed the challenges of designing Nearly Zero Energy Buildings (nZEB) in Nigeria and recommended passive building energy strategies as a solution to reduce high energy use in buildings; however, the study focused on retrofitting existing housing stock and failed to advance the discussion to NZEBs. A similar study was done by (Kang, *et al.*, 2022).

This study is therefore driven by the need to help bridge this gap in knowledge by investigating the status quo of residential NZEBs in Nigeria, the barriers and drivers, and developing a strategic roadmap for achieving decarbonisation of the residential building sector by 2060.

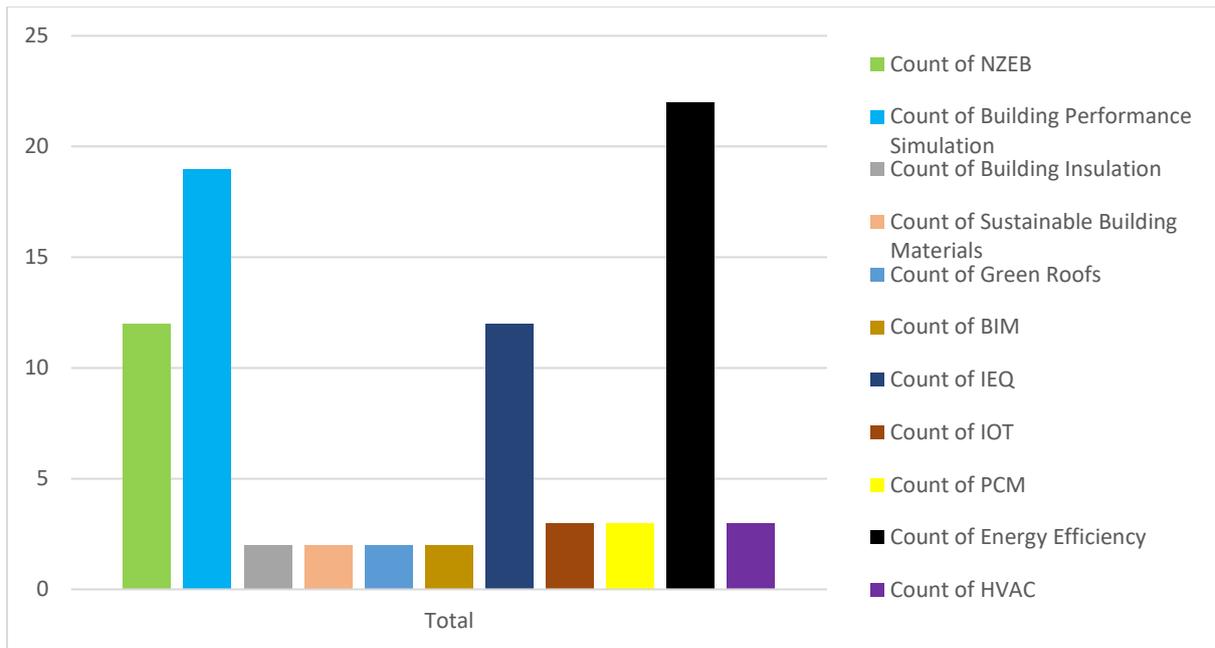


Figure 1.6: Green Building Topic Trend Globally.

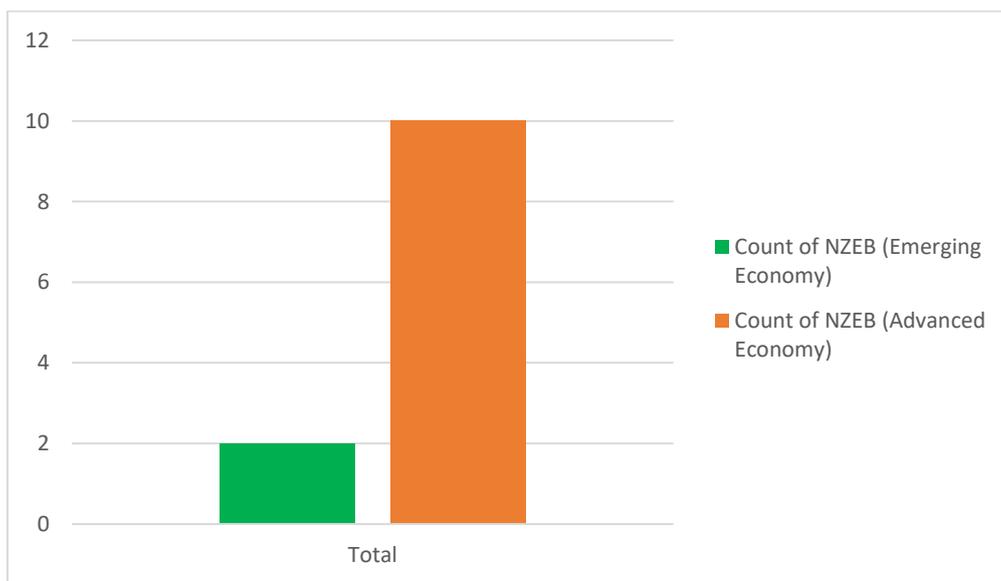


Figure 1.7: Discuss on NZEB in emerging and advanced economy.

Figure 1.6 shows how NZEB discuss compares to other green building topics globally in recent years. The discuss on NZEB in recent years has been progressive, however, when it is contextualised as seen in Figure 1.7, the disparity shows that NZEB has been by far less discussed in literature in the context of emerging economy when compared to advanced economy.

1.6 Research Questions

The research questions to be addressed in this study stem from the gaps in literature. The gaps are issue-based, context-based, and level of analysis based. The research questions are:

- What are the key barriers to achieving NZEBs in Nigeria?
- What are the key drivers of NZEBs in Nigeria?
- How can a strategic roadmap be developed to guide the transition towards Net-Zero Energy in residential buildings in Nigeria by 2060?

1.7 Research Aim & Objectives

Aim

This study aims to develop a strategic roadmap towards achieving Net-Zero Energy Buildings in Nigeria.

This research aim will be achieved through the following objectives:

Objectives

1. To review relevant literature on the concept and status quo of Net Zero Energy buildings in Nigeria to gain existing knowledge and identify the gaps in knowledge.
2. To identify the key barriers hindering the transition to Net-Zero Energy Buildings in Nigeria using a survey questionnaire and an expert interview.
3. To identify the critical drivers of Net-Zero Energy Buildings in Nigeria using a survey questionnaire, an expert interview, and case study reviews.
4. To analyse the collected data employing descriptive and inferential statistics for quantitative data and thematic analysis for qualitative data, to ensure a comprehensive understanding of the barriers, drivers, and strategic pathways towards achieving Net-Zero Energy Buildings in Nigeria.
5. To develop a strategic roadmap for achieving Net-zero Energy in residential new buildings in Nigeria by 2060.

1.8 Contribution to Knowledge

The key contribution of this study is the development of a strategic roadmap at a national level, to achieve residential NZEBs in Nigeria by 2060. This roadmap provides the government of Nigeria with a distinct path to decarbonisation. Additionally, it outlines the actions, regulations, frameworks, and initiatives that policymakers, industry stakeholders, and other relevant actors must take for the country to achieve its NZEB goal by 2060. Other emerging economies can adopt the study's findings to direct their transition to NZEB. The contribution of this research is discussed in detail in Section 6.3.

1.9 Scope and Limits of Study

Some limitations define the scope of this research to ensure that the research outcome satisfies the aim, and objectives and answers the research questions. In addition, the scope and limits of this study will help manage expectations as regards the generalisability of the research outcome.

1. **Residential Buildings:** Residential buildings encounter unique challenges and considerations compared to commercial and other building types (Abdullahi, *et al.*, 2017). This form of building has a distinct energy consumption pattern, occupant behaviours, and lifestyle requirements that impact energy demand and the viability of net-zero energy strategies (Cao, Dai and Liu, 2016a). Residential buildings often have different policy and regulatory frameworks than other building types, as governments may have specific initiatives targeting energy efficiency or renewable energy adoption in residential buildings (IEA, 2011). Consequently, the policy and regulatory frameworks for residential buildings differ from those for other building categories. Moreover, the residential market operates differently than other building sectors, so stakeholders, such as developers and architects, have their own priorities and dynamics that influence decisions regarding NZEB adoption.

By focusing on residential new-builds, this study delves into the specific challenges, analyses the effectiveness of existing policies, identifies gaps, gains a deeper understanding of the market forces influencing the implementation of net-zero energy strategies, and proposes sector-specific solutions.

2. **New Builds:** The study concentrates exclusively on residential new construction, excluding existing buildings. The limitation is required to maintain a focused research scope, as retrofitting buildings presents unique challenges and considerations that necessitate a separate study. In addition, this offers valuable insight into the entire lifecycle of NZEBs, from design and planning to construction and occupancy.
3. **Nigeria and Emerging Economies:** It is essential to contextualise the study as it will make it specific enough for Ph.D. research. While the focus of this study is Nigeria, the findings and recommendations of this study can provide valuable insights and lessons applicable to other emerging economies.

By clearly defining the scope and limits of this study, a foundation for understanding the context of this research has been established.

1.10 Benefits and Beneficiaries

The proposed road map intends to guide building professionals involved in the lifecycle of a building project along the most efficient path to achieving NZEB in residential new builds. The effective

implementation of this roadmap will mitigate the environmental impact of buildings, allow occupants to achieve thermal comfort with minimum energy, reduce the operational cost of buildings, and reduce the pressure on the national electricity grid, thereby addressing the crisis in Nigeria's power sector and fostering economic growth. In addition, the research contributes to the advancement of NZEB knowledge and can be utilised for capacity building. Homeowners, building occupants, developers, industry professionals, policymakers, researchers, and society are among the beneficiaries of this study's outcome. This paves the way for further sustainability advancements in Nigeria's built environment.

1.11 Methodology

This research adopted a mixed-method approach. Adopting this research strategy allowed for a more in-depth examination of the research questions and the full realisation of the research aim. It offers the opportunity to collect quantitative data through a closed-ended survey questionnaire to measure and analyse particular variables. Through an expert interview, this method also captures a wealth of perceptions, experiences, and contextual data. The literature review informed these two instruments; however, the expert interview was additionally informed by the survey questionnaire responses. The quantitative data will be analysed using descriptive and inferential statistics, while the qualitative data will undergo thematic analysis. The integration of the two data categories will inform the development of the proposed strategic roadmap for achieving NZEB in Nigeria's residential sector.

1.12 Thesis Structure

The structure of this thesis is comprised of six (6) chapters. These chapters constitute the fundamental structure of this thesis. The structure of the thesis from Chapter One (1) to Chapter Six (6) is presented below.

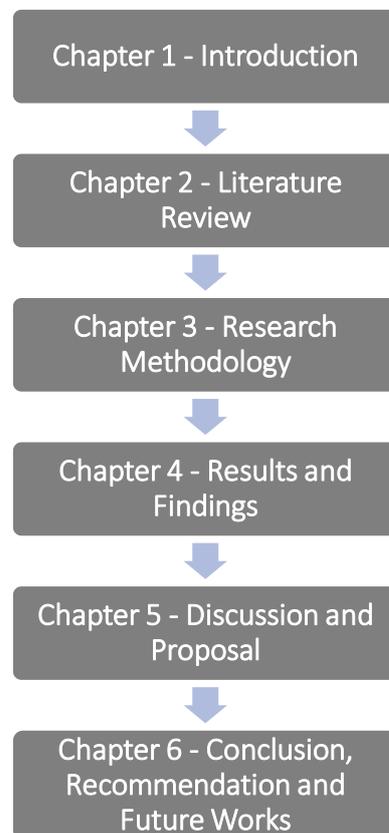


Figure 1.8: Thesis Structure.

Chapter 1 (Introduction)

This chapter establishes the context for the study and provides an overview of the research, including the research background, the research problem, the research question, the research aim and objectives, the research gap, and the research justification. In addition, it discusses the scope and limitations of the study, the benefits and beneficiaries of the research, the research methodology, and the structure of the thesis.

Chapter 2 (Literature review)

In this chapter, a review and synthesis of the extant body of knowledge on NZEBs in emerging economies is carried out, with a focus on Nigeria. It sheds light on previous studies that addressed similar research questions, such as What are the key barriers to achieving NZEBs in Nigeria? What are

the key drivers of NZEBs in Nigeria? And How can a strategic roadmap be developed to guide the transition towards Net-Zero Energy in residential buildings in Nigeria by 2060?

Some of the key literatures reviewed include; The Concept of Net-Zero Energy Building (NZEB), Decarbonisation Status for Buildings and progress since the Paris Agreement – A 2022 Global Review, Status of NZEB in Emerging Economies, Barriers to NZEB market penetration in Emerging Economies, The United Nation’s Sustainable Development Goals (SDGs) 7, 11 and 13, The Impact of COVID -19 Pandemic on the 2050 target, United Nations Framework Convention on Climate Change (UNFCCC) and The Paris Agreement: An Overview, Energy Efficiency in Buildings: A Global Perspective, Nigeria’s Global Commitment on Climate Change, An Overview of Green Building Standards: BREEAM, LEED, Passivhaus, EDGE and NBEEC, The Nigerian Energy Sector, Technological Solutions / Interventions for achieving NZEBs in Nigeria, and Key Factors Affecting Energy Demands in Buildings

Chapter 3 (Methodology)

The methodology chapter provides a comprehensive description of the study's research design, methods, and procedures. It describes how the research questions were operationalized and justifies the chosen research methodology, including the research philosophy, sampling technique, collection methods, and data analysis procedures, as well as the advantages and disadvantages of the chosen method.

Chapter 4 (Data Collection & Analysis)

The fourth chapter of this thesis focuses on data collection and analysis. It describes the instruments used for data collection and explains the technique selected for data analysis. In addition, it presents the results and findings of the analysis and interprets the data with regards to the research objectives.

Chapter 5 (Discussion and Proposal)

This chapter interprets and synthesises the research findings with the existing literature. It addresses the research questions and objectives and discusses how the research findings directly inform the proposed roadmap. The proposed roadmap will be presented and discussed.

Chapter 6 (Conclusion and Future Work)

This is the concluding section of the thesis. This chapter summarises the main findings of the study, reexamines the research questions and objectives, and assesses the degree to which they have been addressed. It discusses the study's contribution to the field of knowledge and emphasises its practical implications. In addition, the chapter describes the study's limitations and makes suggestions for future research and practical application.

1.13. Research Development

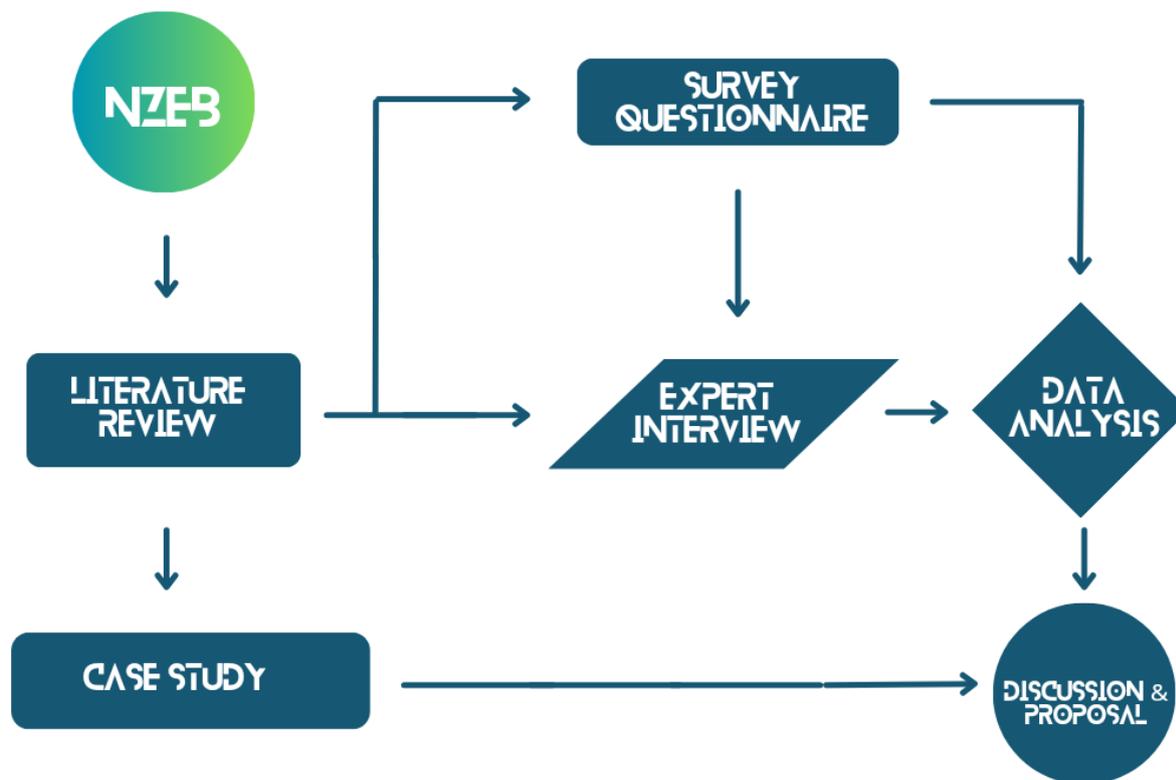


Figure 1.9: Research Development Process

Figure 1.9 illustrates the study's development process. A literature review was conducted to comprehend the extant state of knowledge on NZEBs in emerging economies, with a particular focus on Nigeria, and to identify the knowledge gap to be addressed. Furthermore, a review of case studies on best practices was carried out. This informed the instruments used for data gathering (survey questionnaire, and expert interview). The results of the survey questionnaire informed the questions asked of the experts, and the data from these instruments were analysed and synthesised. The synthesis of the data findings from these instruments and the literature review informed the proposed strategic roadmap.

1.14. Chapter Summary

This chapter has provided an overview of the thesis. Furthermore, it has set the scene for subsequent chapters which will delve deeper into the literature review, research methodology, results and findings, discussion and proposal, conclusion, recommendation, and future works. The following chapter will conduct a thorough review of literature on NZEBs.

CHAPTER 2: LITERATURE REVIEW

2.1 Chapter Introduction

This chapter provides a thorough examination of the various elements of NZEBs, exploring significant subjects that impact their adoption. The literature review encompassed a wide range of themes, such as the global advancements in decarbonising the built environment, the implementation of NZEBs in emerging economies, the alignment of NZEBs and the Sustainable Development Goals (SDGs) set by the United Nations, the impact of the COVID-19 pandemic on NZEB targets, policies and regulations promoting green building practises, energy efficiency in buildings, the specific case of Nigeria as the study's context, and technological solutions for attaining NZEBs in Nigeria. Furthermore, a review of best practices from Colombia and Costa Rica (both emerging economies) was conducted.

Overall, this literature review functions as a comprehensive guide for comprehending the intricate terrain of NZEBs. This study offers significant insights into NZEBs from both a global and regional standpoint. In addition, as this study aims to make a valuable contribution to the field of NZEB, the literature review presented here serves as a robust basis upon which to further develop this research.

2.2 The Concept of Net-Zero Energy Building (NZEB)

The Paris Agreement established the imperative of limiting the global temperature increase to below 2 degrees Celsius above pre-industrial levels, with an even more stringent target of 1.5 degrees Celsius (UNEP, 2022; United Nations, 2017). To achieve this, it was determined that all sectors must achieve full decarbonisation by the year 2050 (Dodoo and Ayarkwa, 2019). It is anticipated that by the year 2050, all sectors of the global economy will transition towards achieving a state of net zero energy (United Nations, 2017).

Buildings account for approximately 40% of global energy consumption and contribute to one-third of greenhouse gas (GHG) emissions (Cao, Dai and Liu, 2016a; Zhang, *et al.*, 2017; Sam and Hui, 2018). Therefore, adopting net-zero energy practises offers a promising avenue to effectively mitigate global energy consumption and GHG emissions while simultaneously enhancing building efficiency.

The concept of NZEB has experienced a surge in popularity in recent years, primarily attributed to the heightened level of awareness generated (United Nations, 2017). Nevertheless, the terms precise definition has proven to be quite elusive, as it varies across different regions and organisations due to divergent perspectives and energy policies (Iwuagwu and Onyegiri, 2019). The principal objective of NZEB is to attain an equilibrium between energy consumption and energy generation, thereby reducing dependence on non-renewable energy sources (Maher, 2020; Mcnabb, 2013). Various definitions have been proposed in an effort to establish a clear and widely accepted understanding of NZEBs. One commonly accepted definition of NZEB is a building that achieves net zero energy

consumption, meaning that the total energy consumed by the building over a year is equivalent to the amount of energy it generates (Feng, *et al.*, 2019b; Wu and Skye, 2021). According to Paul Torcellini, a prominent researcher in the field of NZEB and an acknowledged authority on energy conservation in buildings, NZEB can be defined as a type of building that achieves significantly reduced energy requirements through the implementation of efficiency measures, thereby allowing the remaining energy needs to be met by renewable technologies (Torcellini *et al.*, 2006; Wu and Skye, 2021). According to (Torcellini *et al.*, 2006), an effective definition should give precedence to the concept of energy efficiency, followed by utilising renewable energy sources that are accessible within the immediate vicinity.

In this study, the definition of NZEB proposed by Torcellini has been adopted, as it has gained significant acceptance among scholars engaged in discussions on NZEBs (Abdellah *et al.*, 2017).

NZEBs depend on the incorporation of renewable energy systems to fulfil the remaining energy requirements and attain net-zero energy performance subsequent to the implementation of energy efficiency measures (Torcellini *et al.*, 2014; Abdellah *et al.*, 2017). Renewable energy technologies such as solar photovoltaic (PV) panels, hydropower, wind turbines, geothermal systems, and biomass are frequently utilised (Abdellah *et al.*, 2017). NZEBs have the potential to be implemented in a wide range of structures due to their scalability. Consequently, the selection of renewable energy sources and the sizing of these systems in an NZEB project is contingent upon several factors, including the energy demands of the building, the prevailing climatic conditions, and the availability of resources in the local area (WorldGBC, 2023). Furthermore, integrating energy storage solutions, such as batteries or thermal storage, can be employed to enhance the dependability of energy supply in situations characterised by low renewable energy generation or heightened demand (Abdellah *et al.*, 2017; WorldGBC, 2023).

The concept of NZEBs encompasses a diverse array of resources, with a particular emphasis on energy as the primary focal point (Torcellini *et al.*, 2014; Abdellah *et al.*, 2017). This phenomenon can be attributed to multiple factors, including the substantial carbon footprint and financial implications associated with it. The energy referred to in this context is commonly referred to as operational energy, which pertains to the energy consumed during the utilisation phase (WorldGBC, 2023). It is worth noting that operational energy is responsible for most emissions when compared to embodied energy (Chang, *et al.*, 2019; WorldGBC, 2023). Embodied energy, on the other hand, encompasses the energy emitted during the manufacturing and transportation of building materials and the construction process itself (Kylili, Ilic and Fokaides, 2017; Chang, *et al.*, 2019). While operational energy is the primary source of GHG emissions, addressing embodied energy is crucial for the sector to achieve its goal of complete decarbonisation (WorldGBC, 2023). Furthermore, it is imperative to

integrate and optimise building systems and design strategies in accordance with the specific climatic conditions of the locality.

In summary, NZEBs signifies a notable progression and a fundamental transformation in environmentally conscious architectural design as the international community endeavours to confront the challenges posed by climate change. NZEBs play a significant role in improving energy efficiency, facilitating the complete elimination of carbon emissions from the sector by the year 2050, and fostering a more sustainable built environment. This is accomplished by effectively managing the equilibrium between energy consumption and production. NZEBs are crucial in fostering a more environmentally sustainable and resilient future.

2.3 The Concept of Emerging Economies

Emerging economies, also referred to as emerging markets, are nations undergoing rapid economic growth and industrialisation, transitioning from low-income to middle-income status (Xu and Meyer, 2013; Cavusgil et al., 2013). These economies exhibit several distinctive characteristics that set them apart from advanced economies.

One of the defining features of emerging economies is their rapid economic growth, driven by factors such as industrialisation, urbanisation, and the integration of global markets (Cavusgil et al., 2013). This growth is often accompanied by significant demographic shifts, including a growing middle class, urbanisation, and a relatively young population (Khanna and Palepu, 2011). These demographic changes present both opportunities and challenges for businesses and policymakers.

Emerging economies also undergo institutional transformations, such as the privatisation of state-owned enterprises, the development of regulatory frameworks, and the strengthening of financial systems (Xu and Meyer, 2013). These reforms aim to create an environment conducive to economic growth and attract foreign investment.

Infrastructure development is another critical aspect of emerging economies, as they actively invest in the construction of physical infrastructure, such as roads, ports, and telecommunications networks, to support economic growth and facilitate trade (Khanna and Palepu, 2011). This infrastructure development not only aids domestic economic activities but also enhances the integration of these economies into the global market.

Indeed, increasing global integration is a hallmark of emerging economies, as they become more deeply embedded in the global economy through trade, foreign direct investment, and the adoption of international standards and practices (Cavusgil et al., 2013). This integration presents opportunities

for companies to access new markets and resources but also introduces challenges related to managing cross-cultural differences and navigating complex regulatory environments.

It is important to note that the term "emerging economies" is not a homogeneous category, as these countries exhibit diverse characteristics, challenges, and opportunities (World Bank, 2022). Some of the prominent emerging economies include China, India, Brazil, Russia, Nigeria, South Africa, and Mexico, among others (United Nations, 2020). Understanding the unique contexts and dynamics of each emerging economy is crucial for businesses and policymakers seeking to navigate and capitalise on the opportunities presented by these rapidly evolving markets.

2.4 Decarbonisation Status for Buildings and Progress since the Paris Agreement – A 2022 Global Review

Decarbonising the building sector is of utmost importance in reducing emissions and effectively addressing the broader triple planetary crisis encompassing climate change, nature and biodiversity depletion, as well as pollution and waste (WorldGBC, 2023). According to the Buildings Global Status Report, the building and construction industry constituted 36% of global final energy consumption and 37% of energy-related carbon dioxide emissions in 2022 (UNEP, 2022). There was a notable growth of 16 per cent in green investment and an increase in green building certification in 2021 (Hamilton et al., 2022). However, despite these positive developments, operational emissions in buildings experienced a 2 per cent increase compared to the previous record high observed in 2019 (Hamilton et al., 2022; WorldGBC, 2023). This increase occurred following the easing of the COVID-19 pandemic, while the growth of renewable energy remained relatively modest (WorldGBC, 2023). This observation serves as a strong indication that the sector is in dire need of a more comprehensive strategy in order to make significant progress towards attaining the 2050 goal. To effectively mitigate future emissions, it is imperative to prioritise the augmentation of green investments and the implementation of strong national policies. Additionally, the development of building codes that actively strive towards achieving net-zero emissions is crucial.



Figure 2.1: 2021 GBCT for the Decarbonization of buildings

(Source: Hamilton et al., 2022)

The Global Buildings Climate Tracker (GBCT), as depicted in figure 2.1, monitors the advancement of decarbonisation within the building industry. The tracker employs 2015 as the reference year, designating it as point 0, while setting point 100 for the year 2050, which represents the desired target year for attaining NZEB. The portion highlighted in green within the diagram depicted in Figure 2.1 illustrates the advancements achieved thus far with the 2050 NZEB objective. As of 2021, the current level of progress stands at 8.1 points. This represents a decrease compared to the previous year (2020), which recorded the highest point of 11.3 since 2015. However, it should be noted that this figure still indicates progress when compared to the level of 4.8 points observed in 2019. The available data suggests that the progress made in decarbonisation during the year 2020 can be primarily attributed to the occurrence of the pandemic. However, it is evident that no substantial advancements have been made towards attaining the 2050 target. Figure 2.2 presents a comprehensive visualisation.

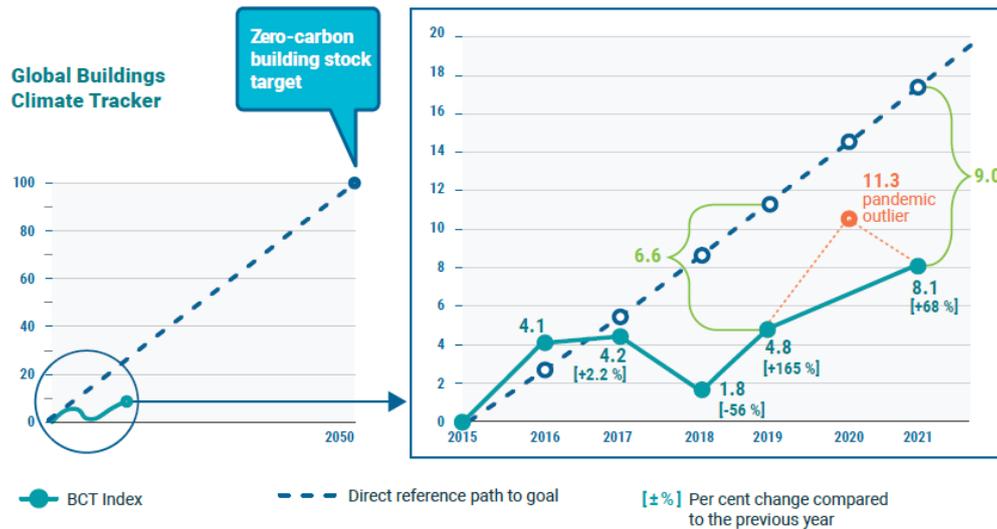


Figure 2.2: 2021 GBCT for the Decarbonisation of buildings

(Source: Hamilton et al., 2022)

The diagram in Figure 2.2 illustrates a discontinuous blue line that connects the initial year of 2015, commencing at point 0, to the desired year of 2050, terminating at point 100. The graph on the right depicts a blow-up graph illustrating the current decarbonisation progress, represented by a blue line, starting from the baseline year of 2015 and extending towards the desired target year of 2050. In the year 2016, the observed decarbonisation point exhibited superior performance in comparison to the intended decarbonisation trajectory. Despite experiencing a 2.2% increase compared to the preceding year, the decarbonisation progress observed in 2017 remained insufficient to align with the desired trajectory. Since then, there has been a growing disparity between the intended decarbonisation trajectory and the realised decarbonisation outcomes. The year 2020 witnessed a notable increase in decarbonisation efforts. However, it is important to note that this surge can be attributed to the temporary economic slowdown caused by the COVID-19 pandemic, particularly in the built environment sector. The reduced activity in non-residential buildings, such as office spaces, played a significant role in this trend. Therefore, it is crucial to avoid misinterpretation and acknowledge that this isolated event does not necessarily indicate that decarbonisation is progressing as expected.

To align with the objectives outlined in the Paris Agreement by the year 2050, it is imperative that the trajectory represented by the blue line remains at or above the threshold indicated by the broken line.

2.5 NZEB in Emerging Economies: An Overview.

This section focuses on the specific context of emerging economies, which is the primary area of research in this study. It provides an overview of the significance, current status, challenges, and opportunities associated with NZEB.

2.5.1 The Significance of NZEB in Emerging Economy

The population of emerging economies is expected to experience an exponential rise by the year 2050 according to projections (GlobalABC, 2020; UNEP, 2022). It is anticipated that this particular geographic area will undergo a substantial process of urbanisation, leading to a notable escalation in the demand for energy resources (IEA, 2023; GlobalABC, 2020). However, this development is not devoid of repercussions. The substantial rise in energy demand will burden the current energy infrastructure, which is presently insufficient and unreliable (United Nations, 2017; WorldGBC, 2023). Moreover, a significant proportion of emerging economies heavily depend on fossil fuels, thereby exacerbating the issue of climate change (Byrareddy, 2022; BII, 2022). NZEB addresses this energy crisis. NZEB is equipped with the capacity to substantially decrease energy consumption and dependence on fossil fuels, thereby alleviating strain on the energy infrastructure and mitigating environmental consequences (Karlessi, *et al.*, 2017; Fong and Lee, 2012; Wu and Skye, 2021).

The significance of NZEBs in emerging economies extends beyond the scope of energy conservation and environmental consequences (WorldGBC, 2023). The region presents numerous prospects, including a favourable local market for potential investors, employment possibilities for the local population, and an enhanced standard of living (Fong and Lee, 2012). The adoption of NZEBs in emerging economies will not only yield advantages for these nations but also make a significant contribution to the global endeavour of mitigating climate change and fostering a sustainable future.

In conclusion, the importance of NZEBs in emerging economies is expected to rise in tandem with the ongoing population growth and urbanisation trends observed in this region. Hence, it is crucial for the governments of these nations to give utmost importance to energy efficiency and engage in partnerships with industry stakeholders, international organisations, the private sector, and research institutions. This collaboration aims to formulate effective policies and regulatory frameworks, raise awareness, promote the adoption of best practises, facilitate the exchange of knowledge, and enable the development of skills and capabilities.

2.5.2 Status of NZEB in Emerging Economies

The status of NZEBs in emerging economies exhibits considerable variation, with a generally limited level of adoption observed across these regions (GlobalABC, 2022). Although a limited number of countries have made notable advancements in the adoption and implementation of NZEBs, most

nations are still in the initial phases of embracing this concept (Feng, *et al.*, 2019b; UKGBC, 2022). For example, nations such as China, recognised as the largest emerging economy, have made significant strides in their pursuit of the net zero target by implementing the Green Building Labelling Programme and allocating substantial investments towards NZEBs (He, *et al.*, 2018; Doan *et al.*, 2017; Cao, Dai and Liu, 2016a). Conversely, countries like Nigeria are currently in the nascent stages of NZEB adoption, indicating a considerable lag in their progress (Wuni, Shen and Osei-Kyei, 2019). The limited adoption of NZEB in emerging economies can be attributed, in part, to a variety of distinctive factors, including but not limited to competing priorities, inadequate policies and regulations, and limited resources (Abdullahi, *et al.*, 2017; IPEEC, 2018). Nevertheless, the increasing recognition of the advantages associated with environmentally friendly practises in the built environment offers a substantial prospect for the broader implementation of NZEB.

2.5.3 Barriers to NZEB market penetration in Emerging Economies

Various obstacles and uncertainties have impeded the market penetration of NZEBs in emerging economies (Oyalowo, Ohiro and Oginni, 2020). However, there are four significant barriers that play a crucial role in emerging markets: competing priorities, limited access to finance, insufficient technical expertise, and restricted access to local materials (Abdullahi, *et al.*, 2017; Oyalowo, Ohiro and Oginni, 2020; Wells, Rismanchi and Aye, 2018; Wuni, Shen and Osei-Kyei, 2019)

Competing Priorities: Energy efficiency in emerging markets often encounters competition from other development priorities, including but not limited to economic concerns, security challenges, educational needs, social issues, and infrastructure development (Norman and O'Regan, 2021). Budgetary planning places a significant emphasis on development priorities, resulting in the governments of these nations allocating minimal or no resources towards energy efficiency projects (UNIDO, 2021). Moreover, the governments of these nations exhibit hesitancy in formulating policies and establishing regulatory frameworks that would expedite their adoption due to their perceived lack of priority (UNIDO, 2021). By effectively mitigating this obstacle, emerging economies can expedite the implementation of NZEB.

Access to Finance: The availability of financial resources plays a pivotal role in expediting the uptake and execution of NZEBs in emerging economies (Marquez, *et al.*, 2015). Accessing finance for NZEB projects can be challenging for developers in emerging economies (UNIDO, 2021). There are multiple factors that contribute to this phenomenon, including the challenges faced by financial institutions in verifying the savings associated with NZEB projects as well as the lack of clarity regarding payback periods (UKGBC, 2022). By facilitating the reduction of this disparity, the market for NZEBs in this

particular region will likely witness increased developer interest, thereby contributing to the success of the objectives outlined in the Paris Agreement.

Lack of Technical Expertise: The effective adoption of NZEB in emerging economies necessitates a certain degree of expertise and proficiency in energy-efficient design, renewable energy technologies, and building energy management systems (Karlessi, *et al.*, 2017; Fong and Lee, 2012; Wu and Skye, 2021).. Hence, there is a necessity for enhanced local technical proficiency in emerging markets. Furthermore, it is imperative to situate technological solutions within the specific context of the local climate, local economies, and local culture, among other factors. The acceleration of NZEB adoption will be facilitated by the enhancement of local capacity in these regions.

Access to Local Materials: One of the fundamental barriers faced in emerging economies is the limited availability of local resources, specifically spare parts required for the operation and maintenance of NZEBs (Karlessi, *et al.*, 2017; Fong and Lee, 2012; Wu and Skye, 2021). The effective use of locally sourced materials has the potential to mitigate environmental impact, lower costs, and contribute to the development of local economies (Abdullahi, *et al.*, 2017). By leveraging local resources, emerging markets have the potential to develop a built environment that is more resilient, energy-efficient, and environmentally sustainable.

In summary, a comprehensive strategy that entails the cooperation of governmental entities, private enterprises, international organisations, and research institutions is necessary to address and surmount these barriers.

2.6 The United Nation's Sustainable Development Goals (SDGs) 7, 11 and 13

The United Nations General Assembly (UNGA) formally adopted the Sustainable Development Goals (SDGs) in 2015 and set a deadline of 2030 for their fulfilment (KMPG, 2020; Ferri, 2015). The United Nations created the set of goals known as the SDGs, which consist of 17 interconnected global goals, with the intention of achieving a sustainable future (Goncalves, 2020; United Nations, 2020; KMPG, 2020). The pursuit of achieving Net-Zero Energy in residential buildings in Nigeria is closely aligned with several SDGs. This research interacts with SDG 7, which focuses on 'Energy Efficiency & Renewable Energy'. Figure 2.5. Additionally, SDG 11, which pertains to 'Sustainable Cities & Communities', is also interconnected with this research. Figure 2.6. Furthermore, SDG 13, which addresses 'Climate Change', is another SDG that interacts with this research. Figure 2.7.

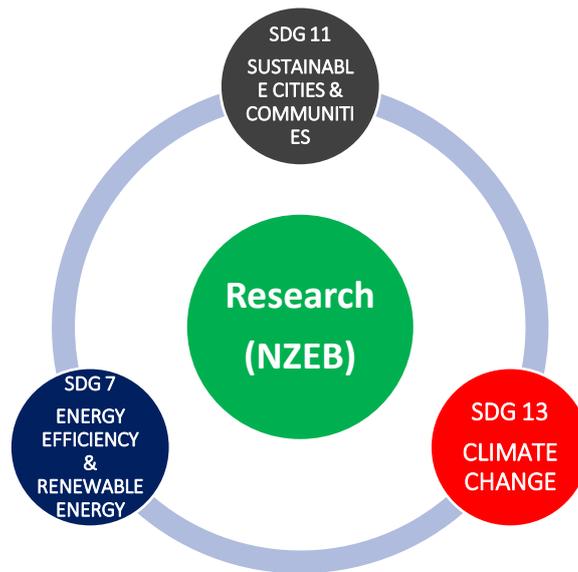


Figure 2.3: Research interaction with United Nations SDGs

(Source: United Nations, 2020)

Figure 2.3 illustrates the interaction between this research and the UN SDGs 7, 11, and 13.

SDG 7 – Affordable and Clean Energy

Energy plays a pivotal role in addressing a wide range of pressing global challenges, including but not limited to climate change adaptation and the development of sustainable urban environments (Geissler, Susanne, Österreicher and Macharm, 2018; Oyedepo, 2012). The persistence of the current status quo will exacerbate the issue of energy affordability and the impacts of climate change. Therefore, it is crucial to transition towards cost-effective and environmentally sustainable sources of energy.

The implementation of SDG 7 is anticipated to facilitate the expeditious advancement of efforts towards the realisation of the objectives outlined in the Paris Agreement pertaining to climate action (United Nations, 2020; Goncalves, 2020; Gautam, 2019). The primary objective is to facilitate the availability of cost-effective and environmentally viable energy sources by implementing a range of approaches, including enhancing energy efficiency, augmenting the worldwide proportion of renewable energy, fostering international collaboration, and encouraging investments in clean energy technologies, among others (United Nations, 2020).

Given its significant contribution to the climate crisis and its comparatively higher energy consumption relative to other sectors of the economy, it is imperative that the building sector assume a prominent position on the global agenda. By incorporating energy-efficient strategies and incorporating renewable energy sources, residential structures have the potential to substantially decrease reliance on fossil fuels and mitigate greenhouse gas emissions. Consequently, this

phenomenon plays a role in enhancing the accessibility of energy, promoting the utilisation of low-carbon energy sources, and ensuring the stability of energy supply.

Within the study context of Nigeria, a considerable segment of the populace experiences a deficiency in accessing a consistent and reliable source of electrical power (Oyedepo, 2012; Jaysawal, *et al.*, 2022). The successful attainment of NZEB in Nigeria would enable households to autonomously produce clean energy and decrease reliance on the national power grid, thereby aligning with the UN SGD 7.

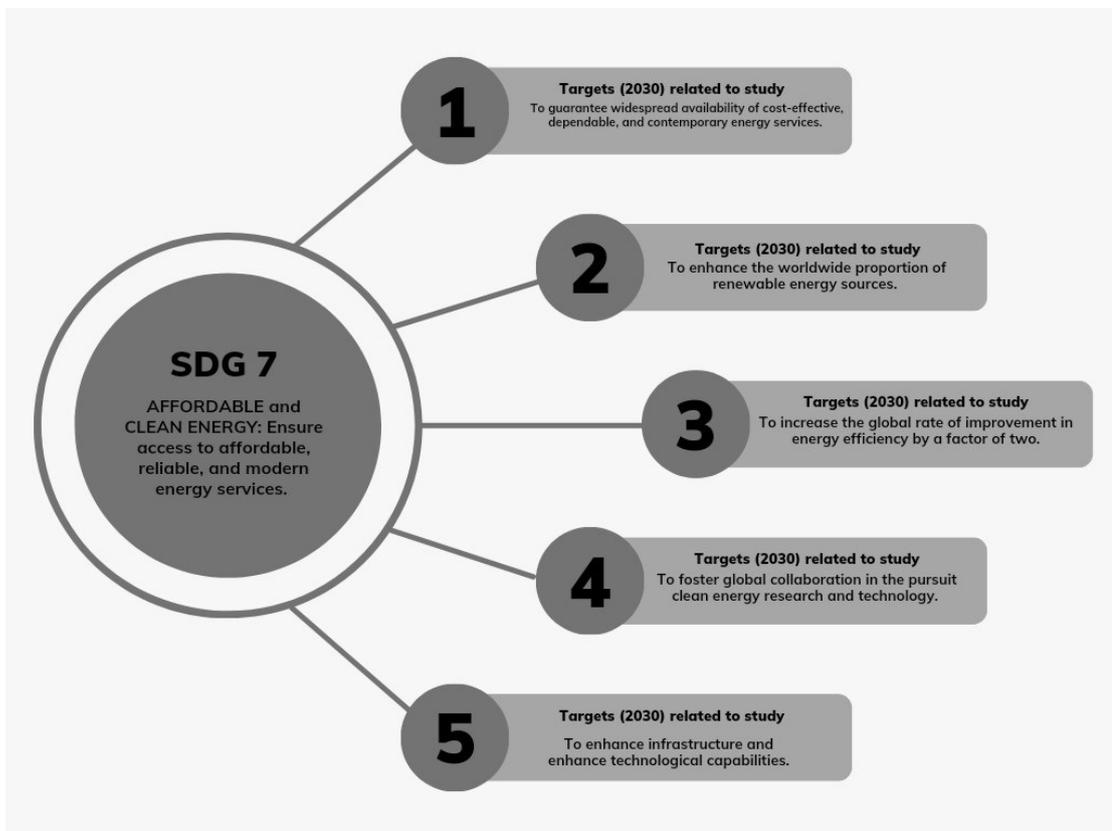


Figure 2.4: United Nations SDG 11 and 2030 targets

(Source: United Nations, 2021)

Figure 2.4 shows the UN's SDG 7 and its objectives to achieve the 2030 targets set by the UN's General Assembly.

SDG 11 – Sustainable Cities & Communities

The primary objective of SDG 11 is to enhance the efficiency of resource utilisation, foster inclusivity, ensure safety, promote resilience, and establish sustainability within urban areas and communities (Goncalves, 2020). Residential structures constitute a fundamental component of urban habitation (Wells, Rismanchi and Aye, 2018). The energy consumption and emissions associated with these

buildings exert a direct influence on the sustainability of urban areas (Wells, Rismanchi and Aye, 2018). Net-zero residential buildings play a significant role in mitigating a city's carbon emissions, thereby fostering the development of a sustainable urban environment and, consequently, a sustainable nation (Goncalves, 2020; Wells, Rismanchi and Aye, 2018).

Attaining the status of NZEB in Nigeria, where rapid urbanisation and population growth present a substantial challenge, holds paramount importance for fostering sustainable urban development. This has a strong correlation with SDG 11.

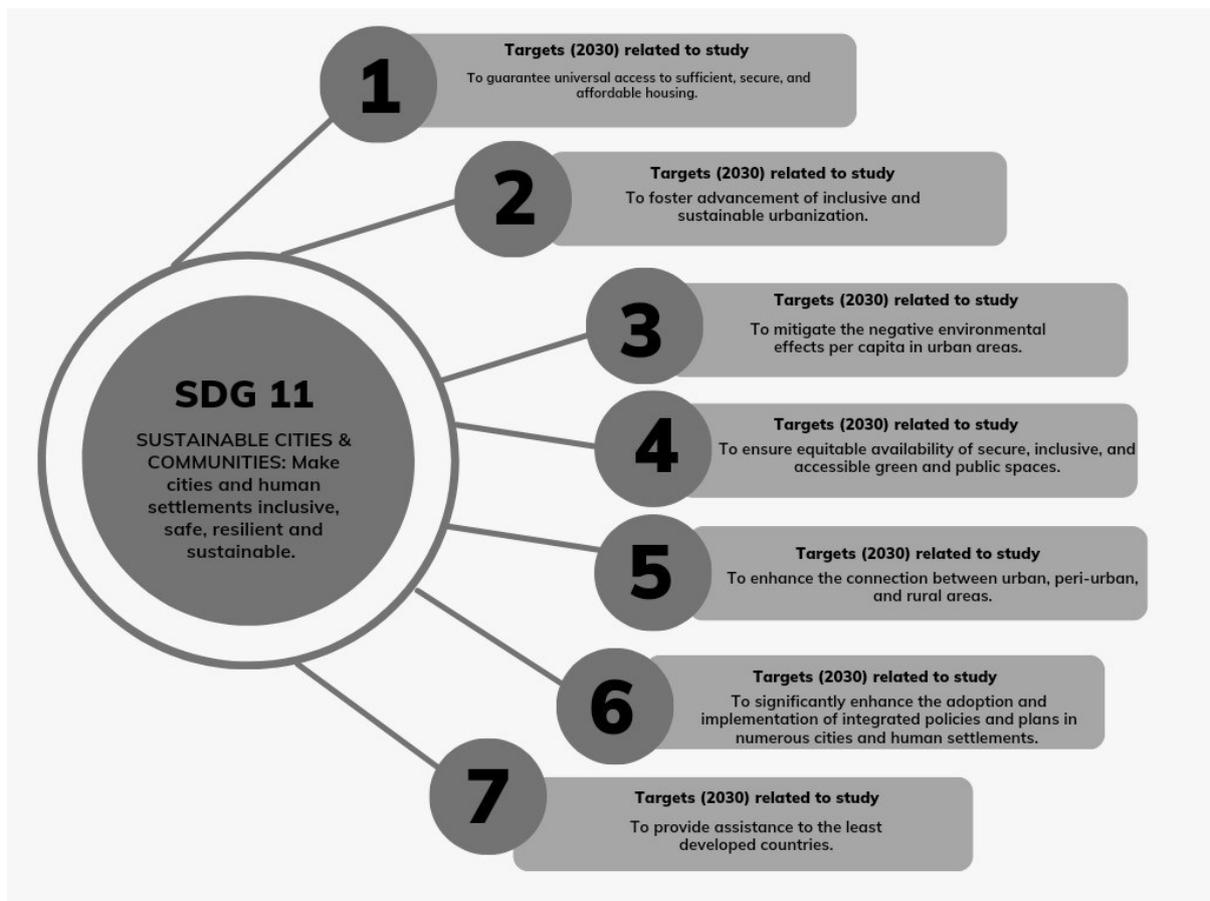


Figure 2.5: United Nations SDG 11 and 2030 targets

(Source: United Nations, 2021)

Figure 2.5 shows the UN’s SDG 11 and its objectives to achieve the 2030 targets set by the UN’s General Assembly.

SDG 13 – Climate Action

Climate change is a pervasive global occurrence that impacts all geographical areas across the planet (Cevik, 2022; Kaya, Yamaji and Akimoto, 2015). According to the United Nations (2021), there is evidence of rising sea levels and temperatures, as well as an increase in the intensity of extreme

weather events. In the year 2019, there was a notable increase in the concentrations of CO₂ and other greenhouse gases within the Earth's atmosphere, reaching an unprecedented peak (United Nations, 2022). The year in question ranked as the second warmest on record, signifying the conclusion of the warmest decade (2010–2019) ever documented (UNEP, 2022; Ferri, 2015). It is imperative to acknowledge that numerous theories have arisen over the course of time to challenge this assertion (Ferri, 2015). Nevertheless, the arguments presented surpass the boundaries of this study.

Addressing the issue of climate change by reducing emissions and implementing adaptive measures is inherently advantageous for a nation. The adverse impacts resulting from climate change often exceed the financial investments required to mitigate them (United Nations, 2022). Transitioning towards a net-zero economy offers significant advantages to the majority of nations, including reduced energy expenditures, enhanced industrial efficiency, heightened energy resilience, improved air quality, and the creation of employment opportunities (Cao, Dai and Liu, 2016a).

SDG 13 focuses on the imperative of addressing climate change through a range of strategies, including the formulation and implementation of national policies, raising awareness, and aligning efforts with the objectives outlined in the United Nations Framework Convention on Climate Change (UNFCCC) (United Nations, 2022).

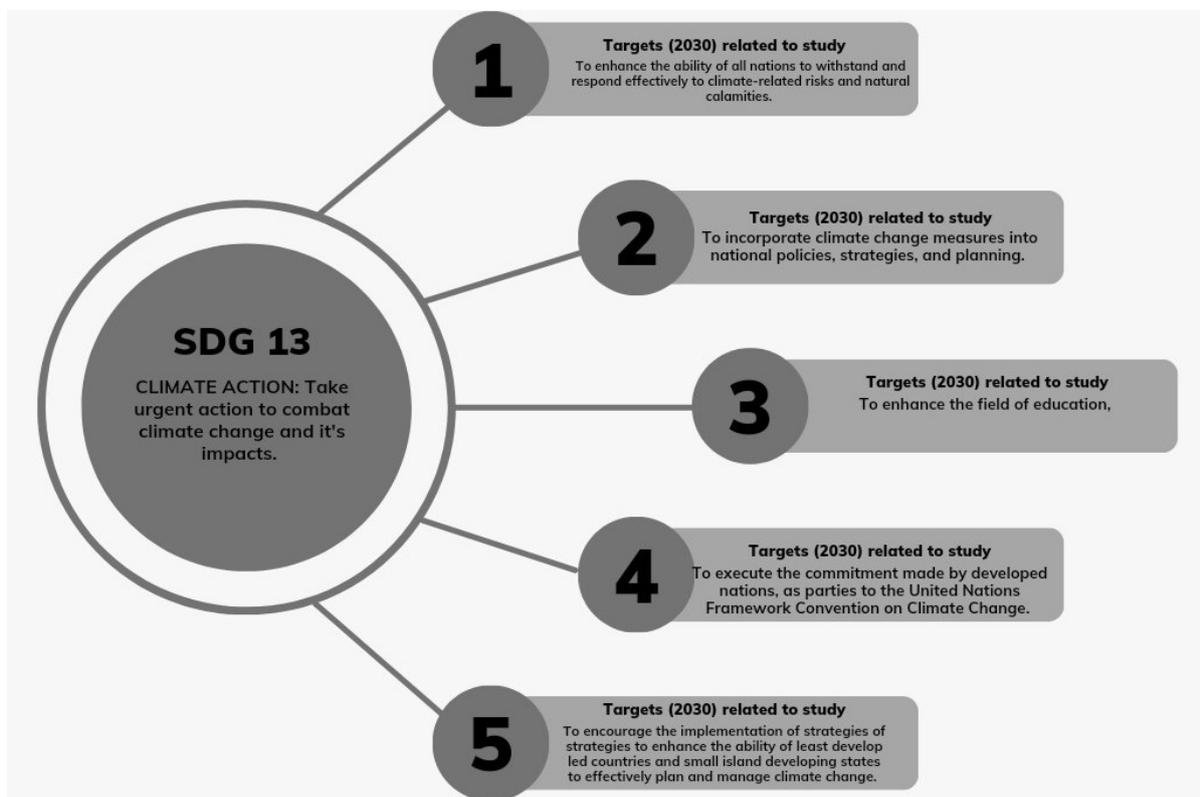


Figure 2.6: United Nations SDG 13 and 2030 targets

(Source: United Nations, 2021)

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2.7 The Impact of COVID -19 Pandemic on the 2050 target.

In the year 2020, the global community experienced an unforeseen global crisis known as the COVID-19 Pandemic (Shulla, *et al.*, 2021; United Nations, 2022). The COVID-19 pandemic has resulted in significant transformations across various facets of our daily existence (Shulla, *et al.*, 2021). Numerous sectors of the economy, with a particular focus on the built environment, have undergone transformations in their methodologies pertaining to work, education, commerce, and other relevant areas (United Nations, 2022; WorldGBC, 2023). The year in question proved to be significant for the global building sector (WorldGBC, 2023). This sector experienced a significant transformation in the prevailing conditions, characterised by a momentous decline in construction operations and restricted utilisation of non-residential structures as a consequence of the global lockdown measures (Crowther, *et al.*, 2022). Consequently, the industry experienced a substantial reduction in GHG emissions during the year 2020, leading to a notable narrowing of the gap between the intended decarbonization trajectory and the actual decarbonisation outcomes (Hamilton *et al.*, 2022). Figure 2.5.

The global response to the pandemic resulted in a significant decrease in GHG emissions and an improvement in air quality (Hamilton *et al.*, 2022). Globally, there was a significant reduction of 60% in air pollution, while there was a notable increase of 129% in the utilisation of bicycles. according to the study conducted by Shulla et al. (2021),

However, the COVID-19 pandemic has provided a distinct opportunity for transformation, as there has been a notable increase in awareness regarding the pressing need for sustainability in recent years (OECD, 2020). Hence, it is crucial to capitalise on the opportunity to reconstruct our society and recuperate from the pandemic in a manner that encompasses the principles of sustainable development. The concept of a "green recovery" has been implemented as a means to support the process of recovering from the pandemic (Shulla, *et al.*, 2021; ADB, 2020). This approach is deemed necessary due to the potential detrimental impact on the environment that would result from a continuation of business-as-usual practises (Erbach, 2020; Friedlingstein, *et al.*, 2021). It is imperative that governmental entities allocate resources towards the implementation of environmentally sustainable systems and extend assistance to the private sector to facilitate a transition towards a greener economy. This can be achieved through the formulation and implementation of policies and the provision of financial incentives (GlobalABC, 2020).

The ongoing pandemic has demonstrated the government's capacity for prompt and decisive action in times of crisis. Therefore, the successful implementation of NZEB relies on the fundamental aspect of

global collaboration. The experiences, decisions, and policies stemming from the COVID-19 pandemic can serve as an invaluable guide for addressing the ongoing global climate crisis.

The current crisis has had a negative impact on various sectors globally, and the manner in which we navigate the recovery process will play a pivotal role in shaping future advancements.

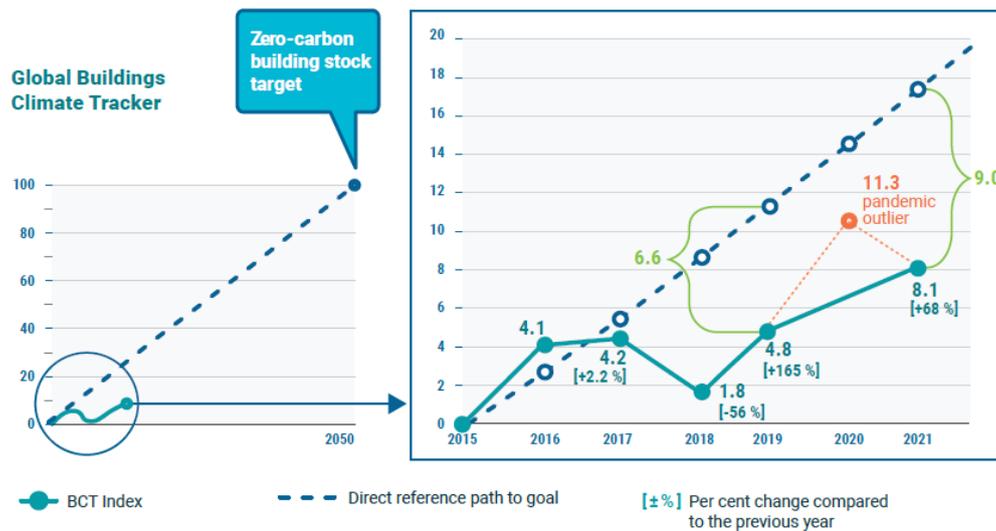


Figure 2.7: 2021 GBCT for the Decarbonisation of buildings

(Source: Hamilton et al., 2022)

Figure 2.7 shows a significant increase in decarbonisation in year 2020. A 6.5 decarbonisation point was gained from the previous year.

2.8 Green Building Policies & Regulations: Global Focus

2.8.1 Building Energy Codes

Building energy codes are a form of regulatory instrument that establishes the minimum standards of energy efficiency for buildings (CIBSE, 2020; Arup, 2017a). It is crucial to enhancing building energy efficiency and attaining NZEB (Arup, 2017a). There is currently a rising inclination in the United States (US) towards the establishment of a building energy code that can achieve net zero energy on-site (Laustsen, 2020). This would be accomplished by implementing rigorous energy efficiency criteria in conjunction with the utilisation of renewable energy sources (CIBSE, 2020). The motivation behind this endeavour stems from the aspiration to attain a state of net zero emissions by the year 2050 (United Nations, 2020). Building energy codes can be classified as either mandatory or voluntary, frequently accompanied by additional incentives aimed at promoting energy efficiency in buildings (Arup, 2017a). The inclusion of various technological interventions, such as high-efficiency heating

and cooling systems, smart and digital control systems, high-performance windows, and insulation, is a common feature found within building energy codes (GlobalABC, 2020). The incorporation of local climates should be a central consideration in the formulation of building energy codes. National building energy codes are implemented at the country level and are applicable to the entire nation (Arup, 2017a). In contrast, local building energy codes are specific to individual states within a country and are primarily observed in federated nations (BEEC, 2017; FMPWH, 2017; Arup, 2017c). It is imperative that building energy codes be extended to encompass both newly constructed buildings and existing structures. As of 2022, approximately 40% of countries have implemented building energy codes that either impose mandatory requirements on a portion of their building stock or offer a voluntary framework (GlobalABC, 2020). Approximately 35 percent of countries have implemented compulsory regulations that require adherence to building codes for certain or all types of structures (GlobalABC, 2020; UNEP, 2022). According to available data, it has been determined that 26 percent of nations possess compulsory building codes that apply to both residential and non-residential structures (GlobalABC, 2020; Ley, 2015).

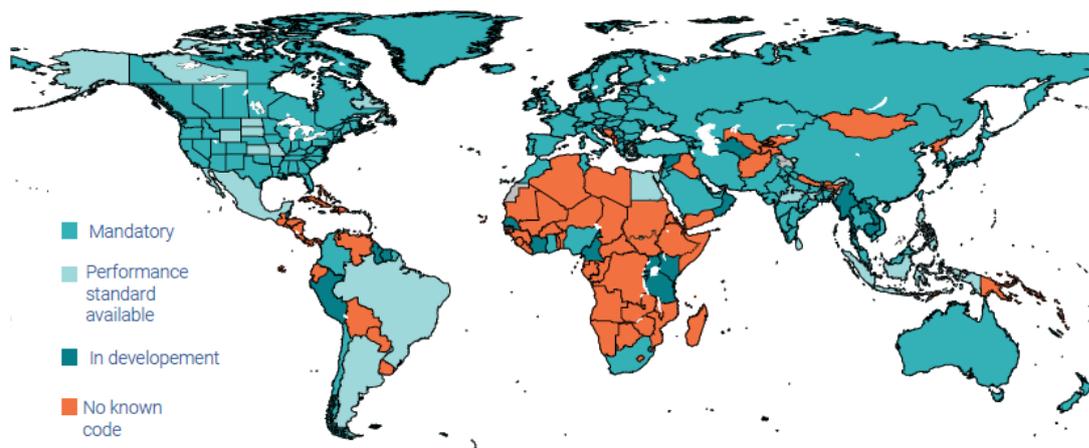


Figure 2.8: Global status of building energy codes in 2021.

(Source: UNEP, 2022)

Figure 2.8 shows a global map of building energy codes as of 2021 tracked by the 2022 Global Status Report for Buildings and Construction. It shows the mapping of ‘mandatory, performance standard available, in-development and no known code’.

Mandatory	68
Performance standard available	11
In development	32
No known code	85
Grand total	196

Figure 2.9: 2022 Global Building Energy Code status.

(Source: UNEP, 2022)

Figure 2.9 shows the global building energy code status as of 2022. 68 countries have mandated their codes, 11 countries have a performance standard available but has not made it mandatory, 32 countries are in the process of developing it while the remaining 85 out of 196 countries doesn't have a known code.

It is important to note that building energy codes focuses on operational energy (Arup, 2017a). However, it is imperative that codes put into consideration embodied energy to achieve total decarbonisation.

2.8.2 Green Building Certification

Green building certifications are in a constant state of evolution as they strive to effectively address the goal of achieving net zero emissions (Arup, 2017a). These certifications serve as increasing evidence of the advancements being made towards the implementation of sustainable practises within the building sector. The World Green Building Council (WorldGBC) is a prominent entity involved in the advancement of green building certifications on a global scale (WorldGBC, 2023). As of 2021, the global count of green building certifications exceeds 70, with WorldGBC serving as the prominent administrator of a substantial portion of these certifications (WorldGBC, 2023)).

Green building certifications serve as a benchmark for sustainable investment and can function as a mechanism to expedite the process of decarbonisation (Arup, 2017a).

Green Building Rating Systems

Africa	Asia	Europe
<ul style="list-style-type: none"> Egypt: Green Pyramid Rating System Kenya: Green Mark South Africa: Green Star SA, Net Zero/ Net Positive Tunisia: EcoBat Uganda: Green Star Uganda 	<ul style="list-style-type: none"> China: Assessment Standard for Green Building of China Hong Kong: BEAM Plus India: IGBC, GRIHA Indonesia: Greenship Japan: CASBEE Lebanon: ARZ rating index Malaysia: Green Building Index Pakistan: Pakistan Green Building Guideline (PGBG) BD+C Saudi Arabia: saaf (Saudi Green Building Forum) Singapore: Green Mark, Singapore Green Building Product/Services Certification South Korea: Korea Green Building Certification Sri Lanka: GreenSL Turkey: B.E.S.T - Residential and Commercial Buildings Certificate United Arab Emirates: PEARL (Abu Dhabi), TARSHEED Vietnam: LOTUS 	<ul style="list-style-type: none"> Austria: DGNB Austria Croatia: DGNB Croatia Denmark: DGBN Denmark France: HQE Germany: DGNB Ireland: Home Performance Index Italy: GBC Home, Historic Building, Quartieri, Condomini Latvia: BREEAM-LV Netherlands: BREEAM-NL, DGBC Woonmerk Norway: BREEAM-NOR Russia: OMIR Spain: DGBN Spain, VERDE Sweden: BREEAM-SE, Miljöbyggnad, CEEQUAL, NollCO2 Switzerland: Minergie, SNBS, DGNB Switzerland United Kingdom: BREEAM, EDGE
<div style="background-color: #cccccc; padding: 2px; text-align: center; font-weight: bold;">North America</div> <ul style="list-style-type: none"> United States of America: LEED, ILFI Zero Energy and Zero Carbon, Parksmart, PEER, RELi, SITES, TRUE, WELL 		
<div style="background-color: #cccccc; padding: 2px; text-align: center; font-weight: bold;">South America</div> <ul style="list-style-type: none"> Brazil: GBC Brasil CASA, GBC Brasil Condomini, GBC Zero Energy Colombia: Casa (Colombia), ICONTEC Guatemala: Casa Guatemala 		
		<div style="background-color: #cccccc; padding: 2px; text-align: center; font-weight: bold;">Oceania</div> <ul style="list-style-type: none"> Australia: Green Star New Zealand: Homestead, NABERSNZ, Carbon zero

Figure 2.10: Geographical areas and their corresponding green building rating systems.

(Source: UNEP, 2022)

The diagram depicted in Figure 2.10 illustrates various geographical areas and their corresponding green building rating systems. It should be noted that the table provided does not encompass all existing green building certifications worldwide, as comprehensive data on this matter is currently unavailable.

2.9 Energy Efficiency in Buildings: A Global Perspective

It is projected that energy consumption will experience a significant increase of 37% by the year 2035 (Ferri, 2015; CIBSE, 2020). Furthermore, it is anticipated that emerging economies will account for 96% of this heightened energy consumption, which can be attributed in part to the substantial growth in population expected by 2050 (Dodoo and Ayarkwa, 2019; World Bank, 2017). Approximately 35% of global energy consumption is attributed to in-use buildings, while the construction and operation of buildings contribute to approximately 15% of annual greenhouse gas emissions worldwide, excluding the embodied energy component (IEA, 2023; Dickinson, 2014; Cao, Dai and Liu, 2016a). The environmental consequences of buildings' energy consumption necessitate the implementation of energy-efficient measures.

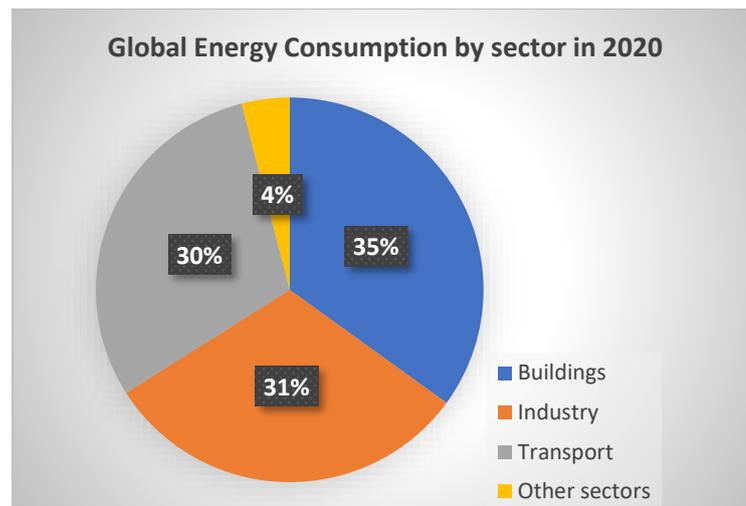


Figure 2.11: Global Energy Consumption by sector (IEA,2020)

Figure 2.11 shows the distribution of energy consumption by sector. The building sector consumes the most as shown in the diagram.

To comprehend the concept of energy-efficient buildings, it is imperative to establish a clear definition. Literatures have defined Energy efficiency in various ways; nevertheless, they all share a common underlying principle, which can be summarised as "less is more". According to CIBSE (2020), energy efficiency can be defined as the utilisation of the necessary internal environment and services while minimising energy consumption in a manner that is both cost-effective and environmentally conscious. It uses less energy to produce the same amount of service (Iwaro and Mwashu, 2019; Seifhashem, *et al.*, 2018; Jas Singh, 2015). Other literatures such as (Dickinson, 2014; Ding, *et al.*, 2018; Khotbehsara, Daemei and Malekjahan, 2019) defined energy efficiency as buildings that strive towards the lowest possible energy requirements with reasonable utilisation of resources using energy-efficient measures.

Global energy consumption has experienced a notable surge, giving rise to apprehensions regarding energy supply issues and the depletion of energy resources (IEA, 2023). Consequently, this has led to various environmental challenges such as global warming, ozone layer depletion, heightened energy demand, and air pollution (Yu, Chen and Wong, 2020). The energy consumption associated with heating and cooling systems in buildings constitutes approximately 30% of the overall global energy consumption and can account for as much as 40% of GHG emissions (Ley, 2015; Arup, 2017a). Consequently, it is unsurprising that there has been an increasing level of interest in NZEBs as a means to address the energy crisis. In the current context, it is imperative to implement significant measures within the building sector. Energy efficiency can be considered a crucial initial measure in addressing the energy crisis (IEA, 2023). This is due to its cost-effectiveness, ability to enhance the value of buildings, thereby providing a competitive advantage in the market, and potential to mitigate

GHG emissions (Ochedi, 2018).

The implementation of various energy-efficient measures in buildings can lead to a significant reduction in CO₂ emissions (Ley, 2015). Some of the measures are optimising the performance of the system for heating, cooling, and supplementary requirements, and the incorporation of daylighting techniques, along with the utilisation of cutting-edge artificial lighting solutions currently on the market (Ley, 2015; Ochedi, 2018).

2.9.1 Key Factors Affecting Energy Demands in Buildings

Various factors ranging from building design and construction, occupant's behaviour and prevailing climatic conditions influence energy demands in buildings (Ochedi, 2018). To achieve NZEB in Nigeria, it is imperative the energy demand in buildings is addressed effectively. These factors are discussed below.

Building Design and Construction: The design and construction of a building are crucial factors that substantial influence on energy demands. This phenomenon can occur in the following ways:

a) Building Orientation: The relationship between building orientation and climate is closely intertwined. The positioning of a building is of utmost importance in determining its energy consumption, as it could be exposed to environmental factors such as sunlight, wind, and other external elements (Valladares-Rendón, Schmid and Lo, 2017; Raji, Tenpierik and van den Dobbelsteen, 2017). When a building is appropriately oriented to align with the sun's trajectory and wind patterns, it has the potential to optimise natural lighting and ventilation (Akande, O. K., 2010; Schnieders, Feist and Rongen, 2015). Consequently, this can lead to a substantial decrease in the reliance on artificial lighting and mechanical cooling systems. Nevertheless, in the absence of appropriate orientation, there is a likelihood of an escalation in the energy requirement for illumination (Ochedi, 2018).

b) Insulation: It plays a crucial role in reducing the energy demand of a building by effectively minimising heat transfer across its walls, roofs, and windows (Lan, *et al.*, 2017;Daghigh , 2015;Taleghani, *et al.*, 2013).

c) Building Envelope: The building envelope plays a significant role in determining the level of human comfort within buildings (Djamila, Rajin and Rizalman , 2018;Huang, Sun and Musso , 2019;Jannat, *et al.*, 2020b). The function of this mechanism is to provide a shield against external environmental elements and regulate the transfer of thermal energy between the interior and exterior surroundings (Taleghani, *et al.*, 2013). The building envelope encompasses components such as the roof, walls, doors, windows, floor, and foundation. Implementing a meticulously planned and executed building envelope, which includes high-performance windows, airtight seals, and reflective building materials, can yield substantial reductions in energy consumption, thereby augmenting overall energy efficiency (Mirrahimi, *et al.*, 2016). In addition, it is imperative for designers to possess a comprehensive

understanding of the characteristics of construction materials and make informed choices that align with the specific climatic conditions of the region. Conduction, radiation, convection, evaporation, and condensation are fundamental mechanisms of heat transfer that necessitate careful consideration in the design of buildings (Huang, Sun and Musso , 2019).

d) Thermal Mass: It refers to the capacity of certain materials, such as concrete or brick, to effectively moderate indoor temperatures by gradually absorbing and releasing heat (Ede, *et al* , 2017;Jannat, *et al* , 2020a;Sadeghifam, *et al* , 2016). This characteristic can significantly mitigate the requirement for active cooling systems in regions with a climate similar to Nigeria's (Lee, Kaneko and Sharifi, 2020; Cetina-Quiñones, *et al.*, 2021; Balaji, Mani and Reddy, 2017).

Building Occupants' Behaviour: The influence of building occupants' behaviour on energy demands in buildings is a critical factor that necessitates designers' understanding of such behaviour (Ochedi, 2018). The extent to which building occupants engage with building systems significantly influences the overall energy consumption of the building, particularly in hot climates, with potential impacts reaching up to 90% (Frontczak and Wargocki, 2011; Zaki, *et al.*, 2018; Miller, *et al.*, 2018; López-Pérez, Flores-Prieto and Ríos-Rojas, 2019). The impact of occupants' behaviour on energy demands within a building can be attributed to their level of awareness and education regarding energy efficiency (WorldGBC, 2023). The absence of sufficient knowledge and education regarding energy efficiency in buildings leads occupants to unknowingly neglect the implementation of energy-saving measures in their daily routines, resulting in substantial financial burdens associated with energy consumption (Müller, *et al.*, 2016; Kartavskaya and Khoroshikh, 2020; Qin and Pan, 2020). Educating occupants of buildings about energy efficiency practises, such as the strategic opening of windows during cooler periods to facilitate natural airflow, maximising the use of natural lighting during daylight hours, and providing information regarding the energy consumption of appliances, can enhance occupants' awareness of their energy usage and contribute to the overall improvement of energy efficiency within buildings. To achieve the desired outcomes of influencing the behaviour of building occupants and optimising energy demands within buildings, it is imperative to foster a collaborative approach involving the building owner, occupants, and energy professionals.

Climatic Conditions: Climatic conditions play a significant role in influencing the energy demand of buildings (Kaya, Yamaji and Akimoto, 2015). Nigeria's climate is distinctive for its high temperatures, humidity, and clearly defined periods of precipitation and aridity due to its geographic location within the tropics (CAT, 2022). As a result, the prevailing climatic conditions in this region will necessitate a substantial need for space cooling, potentially exerting a significant influence on energy consumption. Designers must prioritise designing in accordance with the specific climatic conditions of a given region to effectively cater to the demands of the local market.

This section provided a comprehensive analysis of energy efficiency in buildings from a global standpoint while also examining the primary factors that influence energy consumption in buildings. The subsequent section will provide an in-depth analysis of the study's contextual framework.

2.10 The Study Context: Nigeria

2.10.1 Overview of Nigeria

The World Bank has identified Nigeria as one of the energy hotspots and classified as a Newly Emerging Economy (NEE) (World Bank, 2017). This classification is attributed to Nigeria's rapidly developing economy, which is projected to experience a growth rate of 3.2% according to data from the IEA (World Bank, 2017; IMF, 2018). The nation is anticipated to emerge as a prominent global power, boasting the largest economy on the continent. It currently accounts for 55% of West Africa's Gross Domestic Product (GDP), with Lagos State alone surpassing Ghana's GDP (World Bank, 2017; IMF, 2018). Nigeria holds the distinction of being the most populous country in Africa and plays a significant role as a prominent stakeholder on the continent (World Bank, 2017). The nation continues to exert significant influence on the African continent by virtue of its strategic and financial leadership within the Economic Community of West African States (ECOWAS). Since the establishment of ECOWAS in 1975, Abuja has served as the headquarters of this regional organisation (Kanyarusoke, Gryzagoridis and Oliver, 2016). The attainment of the status of an 'African Global Superpower' necessitates the resolution of various obstacles impeding its progress, including the energy crisis. It is important to note that Nigeria is a member of the West African Power Pool (WAPP), an institution under the Economic Community of West African States (ECOWAS) that aims to facilitate the integration of regional power systems and the establishment of a regional electricity market (WAPP, 2021). Nigeria is anticipated to assume a pivotal role and serve as an essential collaborator within the region to accomplish the objective of decarbonisation (GBCN, 2022). Subsequently, the nation has established highly ambitious decarbonisation objectives within Africa with the intention of assuming a leadership role in climate action within the region. The country aspires to attain net zero emissions by the year 2060 while simultaneously addressing its escalating energy demands and ensuring universal electricity access for its populace (NACOP, 2015). Nigeria has established a target known as the "30-30-30" objective, which entails achieving a grid-connected capacity of 30 GW with a minimum of 30% renewable capacity by the year 2030 (NACOP, 2015).

Geographical Location

Nigeria is situated within the latitudinal range of 4 degrees North to 14 degrees North and the longitudinal range of 2 degrees East to 14 degrees East (World Atlas, 2021). The region under consideration is geographically delimited by Niger to the North, Cameroon to the East, the Benin

Republic to the West, and the Atlantic Ocean to the South. The African nation encompasses a landmass measuring approximately 923,768 square kilometres (356,669 square miles) in total (World Atlas, 2021).



Figure 2.12: Location of Nigeria on world map

(Source: World Atlas, 2021)

Figure 2.12 shows the precise location of Nigeria on the world map with its coordinates.

Population

There exists an interconnection between the population of Nigeria and the phenomenon of climate change. The African nation has experienced significant population growth, ranking among the highest in the world (World Bank, 2021). According to the World Bank (2021), the country's population exceeds 200 million, making it the most populous nation in Africa and one of the most populous globally, representing approximately 2.64% of the total global population. The implications of population growth are manifold, encompassing heightened energy demand, increased CO₂ emissions, the loss of natural habitats, and environmental degradation (IEA, 2021). Consequently, urgent climate action is imperative in Nigeria to mitigate the escalating rate of GHG emissions and mitigate the adverse effects of climate change, as underscored by previous studies (Ochedi and Taki, 2022; IEA, 2023; Geissler, S., Osterreicher and Macharm, 2018; Ley, 2015).

Climate

Nigeria is situated within the tropical region; thus, it is characterised by a tropical climate (World Atlas, 2021). The southern region of Nigeria encounters warm and wet weather conditions, while the northern region experiences hot and dry weather patterns (Ley, 2015). Nigeria experiences an annual temperature range of 23°C to 31°C (Müller, *et al.*, 2016; Ley, 2015). However, it is observed that temperatures can reach a maximum of 43°C during the height of the dry season, while they can decrease to as low as 5°C during the coldest periods of the rainy season (Goncalves, 2020). The dry season is characterised by elevated temperatures, primarily attributed to the absence of convective rainfall that typically mitigates the intensity of afternoon heat (Goncalves, 2020). The annual mean precipitation along the southern coast, situated on the Gulf of Guinea, exhibits a range of approximately 18 mm in the western regions to around 43 mm in specific eastern areas (O.A., I.O. and O.A., 2019). The coastal regions exhibit a reduced duration of the dry season as a consequence of their proximity to the humid oceanic winds. In the inland regions of Nigeria, there is a notable decline in average precipitation, with levels dropping to approximately 13mm across central Nigeria and as low as 5mm in the extreme northern areas, characterised by the arid desert climate of the Sahel region (CAT, 2022). The climate in Nigeria exhibits seasonal variations in temperature, similar to other tropical regions, with two distinct seasons: the dry season and the wet season (Goncalves, 2020). The dry season, spanning from October to April, is characterised by elevated temperatures and reduced humidity levels (Ley, 2015). A dominant north-easterly trade wind that originates in the northern Sahara Desert has an impact on it. This wind, being warm, dry, and laden with dust particles, carries limited moisture as it traverses West Africa and reaches the Gulf of Guinea in the Atlantic Ocean. The remaining five months of the year are characterised by the wet season, which commences with the influx of warm and humid Atlantic air, commonly referred to as the southwest monsoon, into the region (Goncalves, 2020). Precipitation patterns in Nigeria exhibit a south-to-north progression, whereby rainfall initiates in the southern regions and subsequently advances towards the northern areas. The peak of rainfall activity is observed during May, June, or July, encompassing a significant portion of the country (CAT, 2022; World Atlas, 2021). Figure 2.15 illustrates the map of Nigeria with its distinct climatic zones.

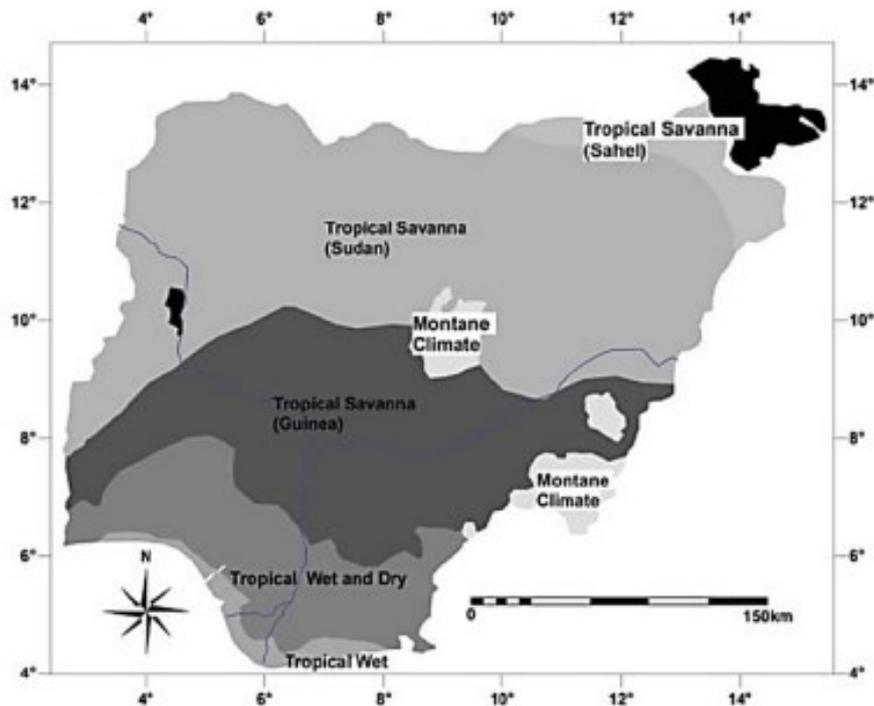


Figure 2.13: Climatic Zones of Nigeria.

(Source: FMPWH, 2015))

Figure 2.13 shows the map of Nigeria with its climatic zones.

2.10.2 Nigeria’s Response to Climate Change

As an emerging economy, Nigeria encounters numerous challenges in its efforts to address climate change, which can be attributed to several factors, including heavy reliance on natural resources and a growing population (CAT, 2022; O.A., I.O. and O.A., 2019). Nevertheless, the Nigerian government has undertaken several measures to acknowledge the pressing necessity of addressing climate change (CAT, 2022). These actions aim to mitigate the adverse effects, adapt to the evolving circumstances, and facilitate a shift towards a future characterised by reduced carbon emissions and enhanced resilience to climate-related challenges. The subsequent text presents Nigeria's response to the phenomenon of climate change.

Climate Change Institutional Framework: Nigeria has developed a comprehensive institutional framework to effectively tackle climate change, encompassing domestic and global dimensions (NCCP, 2021). The Department of Climate Change (DCC), operating under the Federal Ministry of Environment, assumes a leading role in the country's efforts to address climate change at national and international levels (NCCP, 2021). It serves as the central entity responsible for coordinating climate change initiatives and formulating policies in this domain. The organisation collaborates extensively with various ministries via the Inter-Ministerial Committee on Climate Change (IMCCC),

which serves as the primary governing body for climate change matters (NCCP, 2021; CAT, 2022). This collaborative effort involves engaging departments and agencies to incorporate climate change considerations into their respective sectoral policies and plans (NCCP, 2021; CAT, 2022). The IMCCC serves as a forum for facilitating discourse, developing policies, and fostering collaboration among various actors engaged in endeavours related to climate change (NCCP, 2021).

In addition, the establishment of a subnational department known as State Climate Change Departments (SCCDs) has been implemented to effectively support and coordinate climate change initiatives at the subnational level (O.A., I.O. and O.A. , 2019; NCCP, 2021). The primary function of the Subnational SCCDs is to facilitate the harmonisation of national climate change goals with regional interests as well as the incorporation of climate change initiatives into state-level policies and objectives.

Enabling Climate Policies: Nigeria has developed various policies and frameworks that establish a conducive environment for the implementation of climate change actions (NREEEP, 2015). Later in this section, this research will delve into the discussion of several pivotal policies. For example, the National Policy on Climate Change (NPCC) establishes the overarching strategic framework for addressing climate change within the nation (NCCP, 2021; WAPP, 2021). The NPCC places significant importance on the integration of climate change actions into sectoral policies and plans, with the goal of incorporating climate change considerations across multiple sectors of the economy (NCCP, 2021). In addition, the NPCC has formulated policies and strategies tailored to specific sectors in order to effectively tackle climate change concerns. An example of this can be seen in the National Renewable Energy and Energy Efficiency Policy (NREEEP), which aims to facilitate the implementation of renewable energy sources and the adoption of energy-efficient measures (Ochedi, 2018). The National Adaptation Strategy and Plan of Action on Climate Change (NASPA-CCN) provides a comprehensive framework for identifying and prioritising adaptation measures across various sectors (NAP, 2020; NPCC, 2013).

Nationally Determined Contribution (NDC): The Paris Agreement mandates that countries participating in the agreement submit a Nationally Determined Contribution (NDC) that delineates their commitments and contributions to the endeavours of climate change mitigation and adaptation (Goncalves, 2020). The development of Nigeria's NDC took place in 2015, with the subsequent submission of an updated version in 2020 (United Nations, 2020; Goncalves, 2020). The NDC of Nigeria encompasses key areas, namely energy efficiency and renewable energy, which hold significant importance in the context of mitigation efforts. In addition, the nation's NDC underscores its dedication to reducing GHG emissions by 20% by 2030 without any conditions, in comparison to the GHG emissions during the reference period of 2010 to 2014 (NCCP, 2021; NREEEP, 2015).

However, this reduction target could increase to 45% if the country receives assistance, such as climate finance, technology transfer, and capacity building, from advanced economies (NREEEP, 2015). The presence of Nigeria's NDC serves as evidence of its dedication to transitioning towards an economy that is both low in carbon emissions and resilient to climate change. If implemented, these measures would yield substantial benefits, such as enhanced quality of life, increased availability of clean energy, and heightened resilience to climate-related challenges within the nation.

Climate Change Financing: The issue of climate change financing is acknowledged by Nigeria, which acknowledges the insufficiency of government resources to effectively address this matter. Consequently, Nigeria has proactively pursued diverse avenues for climate change funding at the national, regional, and global levels. The subsequent section provides an overview of several sources of climate change finance.

a) International Climate Finance: Nigeria has actively participated in international climate finance initiatives, including its engagement with prominent global climate funds such as the Green Climate Fund (GCF). This engagement primarily aims to secure financial and technical assistance for various climate-related projects within the country (NPCC, 2013; NCCP, 2021).

b) Bilateral and Multilateral Partnerships: The Nigerian government has engaged in collaborative efforts with bilateral and multilateral entities, including the World Bank, African Development Bank (AFDB), and European Union (EU), in order to facilitate knowledge exchange, secure financial assistance, and obtain technical expertise (NPCC, 2013; NCCP, 2021).

c) Domestic Climate Finance: Nigeria has implemented the Nigerian Climate Change Fund (NCCF) as a means to tackle the imperative of domestic resource mobilisation. The NCCF endeavours to gather domestic resources from both the public and private sectors, as well as other domestic stakeholders, with the specific objective of supporting climate change initiatives (NPCC, 2013; NCCP, 2021). In addition, the nation has implemented and distributed Green Bonds as a novel approach and substitute method for generating climate finance. Moreover, the country has published the guidelines for the Green Bonds, which aim to secure approximately \$250 million in climate finance to bolster domestic initiatives in crucial sectors such as energy (NPCC, 2013; NCCP, 2021).

d) Carbon Markets and Climate Investment Funds: Nigeria is actively engaged in exploring opportunities within the carbon market as a means to generate revenue and provide support for climate action (GBCN, 2023). Nigeria has actively engaged in various initiatives, including the Clean Development Mechanisms (CDM), which enable nations to accrue carbon credits through the implementation of projects aimed at reducing emissions. Furthermore, Nigeria has actively engaged in accessing climate investment funds (CIFs) as a means to bolster the advancement of clean energy development and climate resilience projects (GBCN, 2023).

e) Private Sector Engagement: Private sector engagement plays a crucial role in addressing climate change, particularly in terms of mobilising climate finance. The Nigerian government aims to attract private investments in green projects through various mechanisms, including public-private partnerships (PPPs), green bonds, and venture capital funds (NCCP, 2021).

f) Innovative Financing Mechanisms: Nigeria has proactively pursued innovative financing mechanisms, including climate risk insurance schemes and blended finance, as part of its efforts to tackle climate change. These mechanisms aim to offer financial safeguards against climate-related risks and mobilise investments in climate projects by combining resources from both the public and private sectors (NPCC, 2013; NCCP, 2021).

Global and Regional Cooperation: The mitigation of climate change necessitates collaborative endeavours among nations on both a global and regional scale. Nigeria, acknowledging its prominent position in Africa, has made a commitment to pursue effective and equitable international collaboration in addressing climate change (IMF, 2018). Consequently, the country actively engages in various global and regional initiatives pertaining to this issue. Nigeria has made several significant global and regional commitments, such as its adherence to the United Nations Framework Convention on Climate Change (UNFCCC), its participation in the Paris Agreement, its engagement with the African Union and Regional Cooperation, its involvement in West African Regional Cooperation, its participation in South-South Cooperation, and its establishment of various international partnerships (GBCN, 2018).

The following section will discuss these key global and regional partnerships.

2.10.3 Nigeria's Key Climate Change Policies

Nigeria's Climate Change Act 2021: An Overview

Nigeria demonstrates an unwavering commitment to addressing the issue of climate change and aspires to assume a prominent role within the African continent in terms of implementing measures to mitigate and adapt to climate change (KPMG, 2022a). The Climate Change Act of 2021 was enacted on November 18, 2021, with the signature of the President of Nigeria (KPMG, 2022a). The Climate Change Act of 2021 represents a notable milestone in Nigeria's legislative landscape as it seeks to tackle the pressing issues associated with climate change (Oladipo, 2022). The aforementioned legislation represents a pioneering effort in West Africa, as it stands as the first all-inclusive climate change legislation in the region (KPMG, 2022a). Furthermore, it is worth noting that this legislation is one of the few of its kind on a global scale, as indicated by reputable sources such as the International Union for Conservation of Nature (Cevik, 2022; KPMG, 2022a). The legislation establishes a detailed structure for addressing climate-related issues on a national scale and is anticipated to bring about a

significant shift in Nigeria's collective approach to environmental matters, impacting both individuals and organisations. The primary objective of the Act is to secure the necessary financial and material resources for the effective integration of climate change policies and actions with other interconnected policies (Oladipo, 2022). Additionally, the Act establishes a specific timeframe, spanning from 2050 to 2070, within which the goal of achieving net-zero emissions is to be accomplished (Oladipo, 2022; KPMG, 2022a). There will be a departure from the customary operations across all sectors of the economy, affecting each sector. Both the public and private sectors will allocate resources towards the reduction of their carbon footprint and the promotion of sustainable economic growth and development. The legislation promotes the inclusion of a designated climate change officer or environmental sustainability officer within each organisation (Oladipo, 2022; KPMG, 2022a). It is anticipated that the officer will transmit the report detailing their execution of climate change action to the National Council on Climate Change (NCCC).

The enactment of the Climate Change Act 2021 serves as a testament to the country's dedication to addressing the issue of climate change. To effectively execute this legislation, it is imperative to possess sufficient resources, establish an efficient coordination mechanism, and maintain a consistent political determination. The implementation of this strategy necessitates ongoing surveillance and regular revisions, as well as adaptations in response to changing data, technological advancements, and socio-economic factors within the nation. If effectively executed, Nigeria will facilitate the expeditious reduction of its GHG emissions, hasten efforts to attain the country's 2060 target, and accomplish sustainable development (World Bank, 2022).

The National Policy on Climate Change (NPCC): An Overview

The Nigerian government developed the National Policy on Climate Change (NPCC) in 2013 as a comprehensive framework to provide guidance for the country's strategy in addressing climate change (NPCC, 2013). The objective is to incorporate climate change considerations into the formulation of national development plans, policies specific to various sectors, and strategic frameworks (NPCC, 2013). Moreover, the NPCC provides a comprehensive plan for addressing GHG emissions, adapting to climate change, and advancing sustainable development initiatives.

The objectives of the NPCC include mitigating GHG emissions, adaptation to climate change impacts, public awareness, and stakeholder engagement and collaboration (NPCC, 2013).

In summary, the NPCC plays a pivotal role in providing a framework for effectively addressing the challenges posed by climate change.

National Climate Change Policy for Nigeria (NCCP) 2021 – 2030: An Overview

In 2012, the Federal Executive Council (FEC) approved a policy on climate change, the Nigeria Climate Change Policy Response and Strategy (NCCPRS), with the objective of facilitating the advancement of a low-carbon economy, fostering high-growth economic development, and establishing a society that is resilient to the impacts of climate change (FME, 2021; KPMG, 2022b). However, since the launch of the NCCPRS, the global discourse on climate change has evolved. This evolution has subsequently resulted in the implementation of fresh initiatives that have been localised to provide guidance for national efforts in mitigating the consequences and adjusting to this pressing issue. One of the initiatives in question is The National Climate Change Policy for Nigeria (NCCP). The NCCP is a detailed document that outlines strategic policy statements and actions for effectively managing climate change in Nigeria (FME, 2021; Francis, 2022). It serves as a framework for promoting climate-resilient sustainable development across various sectors and facilitating cross-sector collaboration. The primary objective of the NCCP is to lay out a new holistic framework that will effectively guide the nation's response to the developmental implications posed by climate change (FME, 2021).

2.10.4 Nigeria's Global and Regional Partnerships on Climate Change

Climate change is identified as a significant obstacle impeding Nigeria's progress in attaining its National Development Goals (NDG) (Nurlybekova, Memon and Adilkhanova, 2021; O.A., I.O. and O.A., 2019; Rickards and Oppermann, 2018). Climate change is an urgent and widespread issue necessitating collaborative action from the international community (United Nations, 2020; UNEP, 2022). Despite Nigeria's current low contribution of less than 1% to global GHG emissions, it is anticipated that this figure will rise in the coming years (UNEP, 2022; CAT, 2022; IEA, 2023). This increase can be attributed to the projected annual growth rate of 7% and the rapid population expansion, which is expected to double by the year 2050 (United Nations, 2020). Hence, a more ambitious measure is required to fulfil its global obligations. Nigeria has undertaken various international obligations to actively participate in endeavours aimed at combating climate change, encompassing both mitigation and adaptation measures as mandated by the 2015 Paris Agreement, to which it is a signatory (United Nations, 2020). It is noteworthy to acknowledge that Nigeria's dedication to addressing climate change transcends the 2015 Paris Agreement, as the country is a signatory to multiple international conventions and actively participates in various climate change initiatives (FME, 2021). This section provides a comprehensive overview of Nigeria's global dedication to addressing Climate Change, specifically focusing on the international conventions and initiatives to which it is a party.

United Nations Framework Convention on Climate Change (UNFCCC) and The Paris Agreement: An Overview.

United Nations Framework Convention on Climate Change (UNFCCC).

Table 1 provides a comprehensive overview of the UNFCCC and a brief discussion in the context of Nigeria.

Table 1: A summary of the United Nations Framework Convention on Climate Change (UNFCCC)

(Source: Goncalves, 2020)

Type	Multilateral Environmental Agreement
Drafted	9 May 1992
Effective	21 March 1994
Location	Rio de Janeiro, Brazil and New York, United States
Goal	The primary objective of the UNFCCC is to achieve the stabilisation of GHG gas concentrations in the Earth's atmosphere at a level that effectively mitigates the risk of hazardous human-induced interference with the global climate system (Goncalves, 2020).
Discussion	Nigeria has been a signatory to the UNFCCC since its establishment in 1992. Nigeria, as a signatory to this convention, has undertaken a commitment to stabilise GHG concentrations, mitigate the adverse impacts of climate change, foster sustainable development, facilitate the exchange of data and reports on its climate change initiatives, and actively engage in the Conference of the Parties (COP), which serves as the highest governing authority of the UNFCCC.

The Paris Agreement

Table 2 provides a comprehensive overview of The Paris Agreement and a brief discussion in the context of Nigeria.

Table 2: A summary of The Paris Agreement

(Source: Goncalves, 2020)

Type	Multilateral Environmental Agreement
Drafted	30 November – December 2015
Signed	22 April 2016
Effective	4 November 2016
Location	Paris, France

Goals	<ol style="list-style-type: none"> 1. To continue to enhance the worldwide effort to address the issue of climate change by implementing measures that will restrict the rise in global temperatures within this century to a level significantly below 2 degrees Celsius and further limit the increase in temperature to 1.5°C, thereby achieving a state of zero emissions between the years 2030 and 2050 (Goncalves, 2020; United Nations, 2020). 2. To continue to enhance countries' capacity to address the consequences of climate change through establishing suitable financial mechanisms, a novel technology framework, and an improved capacity-building framework (United Nations, 2020).
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In line with the Paris Agreement goals, Nigeria has enacted strategies to substantially cut carbon emissions across its economy (Goncalves, 2020). Nigeria's NDC sets targets to reduce greenhouse gas emissions by 20% by 2030, and conditionally by 45% with international support (World Bank, 2017; United Nations, 2020). Nigeria also has a national climate change adaptation plan (Goncalves, 2020). The country will monitor its climate pledge progress and engage in knowledge-sharing and resource mobilisation efforts for climate mitigation through international collaborations. Nigeria's adherence to its Paris Agreement commitments significantly contributes to the global Net Zero by 2050 target.

African Union Commission (AUC)

The African Union Commission (AUC) serves as the administrative entity of the African Union (AU) and assumes a pivotal role in addressing the issue of climate change (ECOWAS, 2018). The AU, within the context of climate change, endeavours to formulate regional strategies, policies, initiatives, and frameworks that effectively tackle the challenges posed by climate change (ECOWAS, 2018). One of the beneficiaries of this is Nigeria.

Nigeria is a member state and an engaged participant. Nigeria actively collaborates with fellow member states to formulate policies and undertake various initiatives aimed at addressing the issue of climate change (ECOWAS, 2018). Below is an overview of Nigeria's engagement with the African Union Commission (AUC) regarding matters pertaining to climate change.

Policy Development: Under the AUC, Nigeria has contributed to the development of frameworks such as the African Union Climate Policy Framework (AUCPF) and The African Adaptation Initiative (AAI) (ECOWAS, 2018).

Coordination and Advocacy: Through the AUC, Nigeria gets a unified voice on climate change at the global stage with other AUC member states as the AUC coordinates a uniformed stance on climate change amongst member states and advocates for the continent's interests on issues such as equitable access to climate finance amongst others (ECOWAS, 2018).

Capacity Building and Knowledge sharing: Nigeria is a beneficiary of capacity-building initiatives developed by the AUC (ECOWAS, 2018). These programs strengthen Nigeria’s technical capabilities and institutional capacity to effectively address climate change.

Data and Information Management: Data and information management supports evidence-based decision-making at national and regional level. Nigeria is actively involved in regional efforts coordinated by the AUC to improve data collection, analysis and sharing in areas such as climate observations, early warning systems, and climate change impact assessment (ECOWAS, 2018).

Partnerships and Collaboration: Nigeria actively engages with the AUC to facilitate opportunities for collaboration and joint initiatives with other African countries that fosters resource mobilisation, knowledge sharing, best practices etc. (ECOWAS, 2018).

Peer Review Mechanism: The AUC’s peer review mechanism monitors its member states implementation of their climate change commitments (ECOWAS, 2018). This provides Nigeria the opportunity for self-assessment, evaluation, and feedback on its climate change efforts, and to identify areas for improvement.

The National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN)

The National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN) is a comprehensive framework formulated by the Nigerian government to effectively tackle the multifaceted challenges presented by climate change and bolster the nation's capacity to withstand and adapt to its consequences (BNRCC, 2011). The proposed plan offers a comprehensive framework for the systematic incorporation of climate change adaptation strategies across diverse sectors of the economy.

Table 3: The National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN)

(Source: BNRCC, 2011)

Type	Action Plan
Effective	November 2011
Location	Nigeria
Vision	NASPA-CCN envisions the integration of climate change adaptation with sustainable development, reducing the vulnerability and enhancing the resilience and adaptive capacity of all sectors of the economy and of all people to the adverse impacts of climate change.
Goal	The goal is to implement appropriate measures to address the challenges posed by climate change, with a focus on reducing the susceptibility of Nigerians to its impacts and enhancing their resilience and sustainable welfare.

Objectives	The primary objectives of the National Adaptation Strategy and Plan of Action on Climate Change (NASPA-CCN) are to offer direction and support to Nigeria's endeavours in adjusting to the consequences of climate change.
Implementation Strategies:	Below is NASPA-CCN's implementation strategies: (1) Policy Integration (2) Institutional Strengthening (3) Stakeholder Engagement (4) Financing and Resource Mobilisation (5) Capacity Building and Knowledge Sharing
Energy Sector	Goal: The objective of NASPA-CCN, in relation to the energy sector, is to proactively implement measures aimed at mitigating the susceptibility of vital energy infrastructure to the effects of climate change.

Table 3 presents The National Adaptation Strategy and Plan of Action on Climate Change for Nigeria

The incorporation of adaptation into national policies, the creation of sector-specific plans, the encouragement of stakeholder engagement, and the strengthening of capacity by the NASPA-CCN all aid in increasing Nigeria's resilience to the effects of climate change (BNRCC, 2011). Consequently, the implementation of this is of paramount significance.

Section Conclusion

In summary, Nigeria's dedication to addressing climate change on a global scale is evident through its participation in international agreements, implementation of national policies, and formulation of sector-specific strategies. These efforts underscore Nigeria's acknowledgement of the pressing nature of the climate change issue. However, there have been various barriers that have impeded the implementation of these commitments, particularly in the built environment. The barriers were subsequently addressed in this study.

2.10.5 The Nigerian Energy Sector

The Nigerian energy sector plays a pivotal role in the country's pursuit of sustainable development (IEA, 2023). The West African nation encounters notable energy-related obstacles, with one prominent issue being the constrained availability of electricity (Ochedi, 2018; IEA, 2023). Despite improvements in the country's electrical status throughout the years, as illustrated in Figure 2.12, a sizeable portion of the population—93 million people—does not have access to a steady supply of electricity (World Bank, 2017; IEA, 2023). This is roughly 10 per cent of the world's population without access to electricity. The daily electricity production in this economy is currently limited to a mere 30% of the total installed megawatt capacity (Ley, 2015; NACOP, 2015; FMPWH, 2017). Consequently, this insufficiency in supply has contributed to the economy being ranked among the least energy-efficient in the global context (IEA, 2023; World Bank, 2017). The constrained availability of electricity persists as a significant impediment to the nation's holistic progress. The rapid growth of the population has led to a heightened need for energy; however, regrettably, the nation relies heavily on fossil fuels, specifically oil and gas, as its primary energy sources. The excessive

dependence on fossil fuels has led to inefficiencies in energy utilisation and the degradation of the environment (Ley, 2015; FMPWH, 2017). The current situation has unequivocally revealed that the sector is confronted with an urgent crisis, necessitating the implementation of a green transition as the sole feasible solution. Net-Zero Energy Buildings have the potential to decrease dependence on centralised energy infrastructure and facilitate the growth of electricity accessibility (Feng, *et al.*, 2019a; Iwuagwu and Onyegiri, 2019). This is due to the fact that households and communities will have the capability to generate their own electricity, thereby diminishing their reliance on the national grid. Efforts have been undertaken in the pursuit of this transition; nevertheless, a substantial amount of additional effort is required.

Energy Use per Sector

According to the Federal Ministry of Power, Works, and Housing (FMPWH), the largest proportion of electricity consumption in Nigeria is attributed to households, accounting for approximately 78% of the total electricity generated (FMPWH, 2017). This percentage surpasses that of other sectors. The capacity of off-grid diesel and petrol generators totals 3GW and 1.3GW respectively (World Bank, 2017). This is nearly equivalent to the total installed power plant capacity estimated at 6.2 GW in 2011 (FMPWH, 2017).

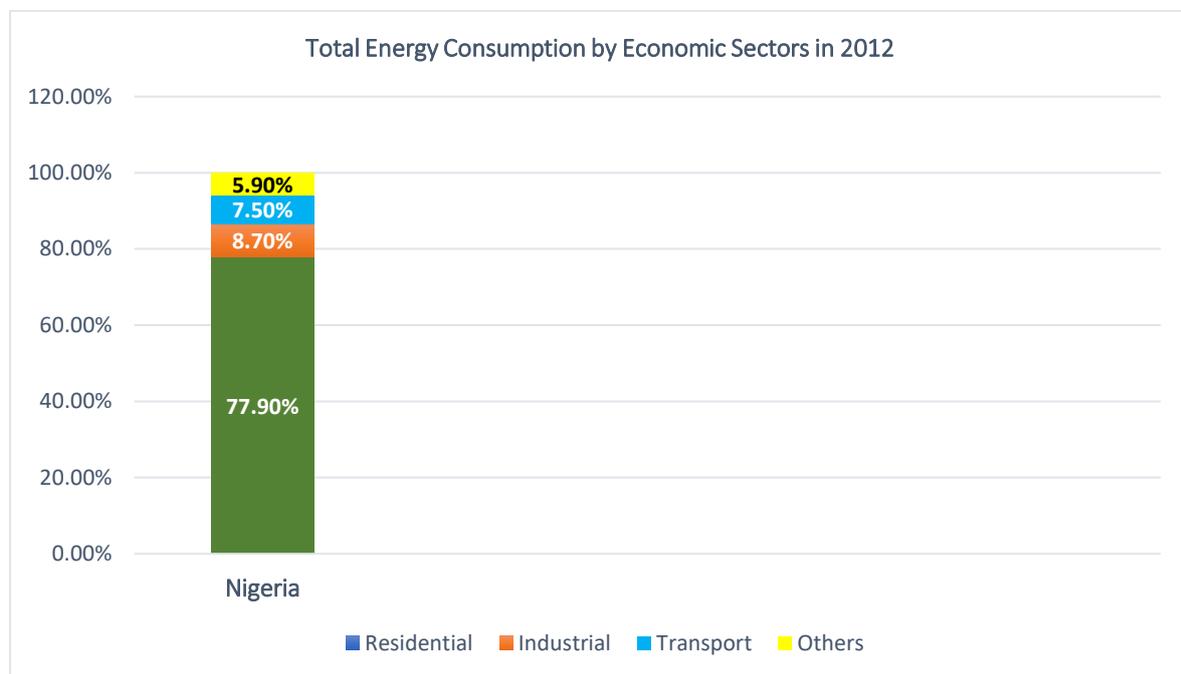


Figure 2.14: Total Energy Consumption by Economic Sectors

(Source: GIZ, 2020)

Figure 2.14 illustrates the total energy consumption by economic sector in Nigeria. The residential sector accounts for the largest proportion of energy consumption, representing 77.9% of the total energy consumed.

Nigeria’s Energy Transition Plan (ETP) 2060: An Overview

Nigeria has expressed its commitment to achieving the objectives outlined in the Paris Agreement, specifically aiming to attain a state of net zero emissions by the year 2060 (United Nations, 2022). The approach taken to achieve this objective is among the most ambitious on the African continent. The Nigeria’s ETP encompasses a comprehensive timeline and framework that outline strategies for reducing emissions in five key sectors, namely Power, Cooking, Oil and Gas, Transport, and Industry (ETP, 2021; IEA, 2023). The use of gas as a transitional fuel will be of paramount importance in the implementation of the transition plan. In order to attain a state of net-zero emissions by the year 2060, it has been projected that a sum of approximately \$1.9 trillion in investments will be necessary (ETP, 2021).

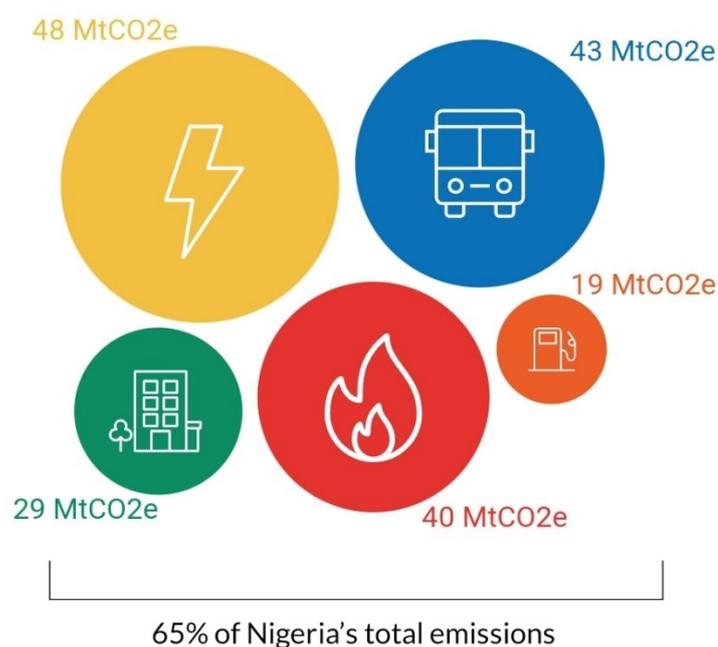


Figure 2.15: 5 key sectors of the Nigeria’s ETP

(Source: ETP, 2021)

The diagram depicted in Figure 2.15 illustrates the five (5) sectors encompassed within the purview of Nigeria's ETP. It involves about 65% of Nigeria’s total emissions. The power sector is identified as the sector with the highest level of emissions, accounting for 48 million metric tonnes of carbon dioxide equivalent (MtCO₂e) out of the total emissions. This corresponds to a value of 27%. The transport

sector ranks closely behind, accounting for 43 MtCO₂e. The cooking sector, industry, and oil and gas collectively account for 40 MtCO₂e, 29 MtCO₂e, and 19 MtCO₂e, respectively.

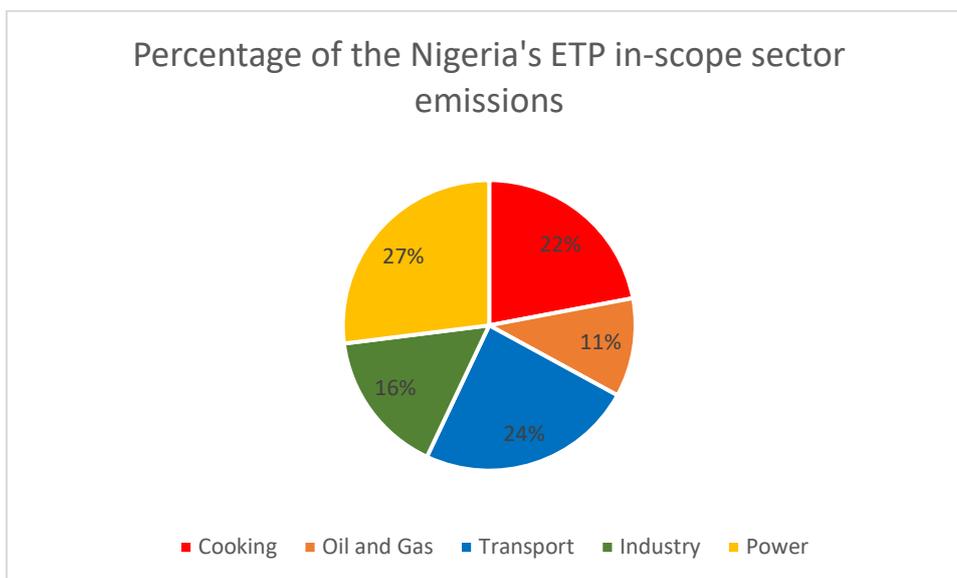


Figure 2.16: Percentage of the Nigeria's ETP in-scope sector emissions

(Source: ETP, 2021)

Figure 2.16 illustrates the percentage allocation of sector emissions within the scope of Nigeria's ETP. The power sector accounts for the largest proportion of emissions, contributing 27% of the overall total. This corresponds to a quantity of 48 MtCO₂e. The transport sector is the second largest contributor to total emissions, accounting for 24%, or approximately 43 MtCO₂e. The cooking sector, industry, and oil and gas comprise 22% (40 MtCO₂e), 16% (29 MtCO₂e), and 11% (19 MtCO₂e) of the total emissions, respectively. Table 4 shows Nigeria's ETP decarbonisation strategy for each sector.

Table 4: Nigeria's ETP decarbonisation strategy by sector

(Source: ETP, 2021)

Sector	Decarbonisation Strategy
Power - Including electricity generation, both on and off grid.	The complete eradication of diesel and petrol generators, along with the augmentation of power generation capacity through the utilisation of renewable sources, particularly solar energy.
Industry	The implementation of clinker substitution with calcined clay and the utilisation of Bioenergy with Carbon Capture and Storage (BECCS) in the cement manufacturing process, the substitution of grey hydrogen (hydrogen produced from fossil fuels) with green and blue hydrogen in ammonia production, and the adoption of zero-emission fuels like clean electricity and hydrogen for heating in lieu of natural gas and biomass.
Transport	Transitioning to low-emission transport technologies and mode-shifting, especially for passenger vehicles which accounted for 72% of transport emissions in 2020, is a focus area. Biofuel blending can serve as a temporary strategy during the transition to an electric-oriented transport

	system.
Oil and Gas	Fugitives - Instrument air systems, vapour recovery units on storage tanks, replace compressor rod packaging and quarterly leak detection and repair. Venting and Flaring - Improved flaring efficiency, exporting/repurposing gas Upstream Energy Emissions - Increased run time of key equipment, equipment optimisation through artificial intelligence (AI), upgrading single-cycle gas turbine (SCGT) plants to combined cycle gas turbine (CCGT) plants, steam boiler, process electrification.
Cooking	A move from traditional firewood, charcoal, and kerosene to Liquefied Petroleum Gas (LPG) (until 2030), efficient wood stoves, electrification, and biogas (particularly in rural areas). Biogas and electric cookstoves are prioritized for deployment post 2030 since they are carbon neutral.

Table 5 presents Nigeria's ETP decarbonisation strategy by sector

Nigeria's Renewable Energy Policies

As previously mentioned in this study, the concept of NZEBs entails the integration of energy efficiency strategies and the utilisation of renewable energy sources (Ochedi, 2018). To achieve NZEB in Nigeria, it is imperative for the Nigerian government to acknowledge the role of renewable energy within the context of NZEB. Over the course of time, numerous policies and initiatives have been formulated with the aim of promoting the adoption of renewable energy. Some of these policies and initiatives include the National Renewable Energy and Energy Efficiency Policy (NREEEP) (Federal Ministry of Power, 2015), the Renewable Energy Master Plan (REMP) (Energy Commission of Nigeria, 2005), various Energy Efficiency programmes, the Nigerian Electricity Regulatory Commission (NERC) (NERC, 2022), the Rural Electrification Agency (REA) (REA, 2020), the Renewable Energy Fund (REF), and the Feed-in Tariff (FiT) Programme (Federal Ministry of Power, 2016).

1. National Renewable Energy and Energy Efficiency Policy (NREEEP)

The policymakers possess an understanding of the significance of implementing a renewable energy policy that is interconnected with an energy efficiency policy, which has led to the establishment of the National Renewable Energy and Energy Efficiency Policy (NREEEP) (Emodi and Boo, 2015). The NREEEP facilitates the integration of energy-efficient measures with renewable energy sources, thereby fostering synergistic outcomes (Federal Ministry of Power, 2015; NREEEP, 2015). The aim of this policy is to facilitate the advancement and adoption of renewable energy sources and energy efficiency measures while effectively harnessing the nation's energy resources (Federal Ministry of Power, 2015; Oyedepo, 2012). The primary emphasis of the NREEEP lies in the development and utilisation of various renewable energy sources, including hydropower, biomass, solar, wind, geothermal, wave, and tidal energy power plants (NESP, 2015). Additionally, the programme recognises the significance of cogeneration plants for energy production and acknowledges energy efficiency as a supplementary means of

energy generation (Akuru and Okoro, 2014). However, it is anticipated that a revised iteration of this policy will encompass a broader range of renewable energy sources, contingent upon advancements in both international and local technological spheres. Moreover, it encompasses a wide range of concerns pertaining to renewable energy and energy efficiency, including matters related to legislation, regulation, and standards, as well as the development of capabilities (FMPWH, 2017).

Before the establishment of the NREEEP, previous attempts were made to formulate comparable policies that aimed to tackle renewable energy and energy efficiency concerns. However, these policies lacked a comprehensive framework tailored to the specific issues at hand and failed to adequately address the distinct requirements of the electricity sector in relation to its restructuring and privatisation policies (FMPWH, 2017). In addition, the implementation of a national-level renewable energy and energy efficiency policy was deemed crucial to attract foreign investors who expressed a desire to invest in Nigeria's economy (Emodi and Boo, 2015). However, it was imperative that this policy be aligned with a comprehensive national programme strategy. Consequently, the NREEEP effectively addressed this gap.

2. Renewable Energy Master Plan (REMP)

The Renewable Energy Master Plan (REMP) was formulated in 2006 with the aim of offering direction and guidance to Nigeria's endeavours in the advancement of renewable energy sources (Ley, 2015; NPCC, 2013; IEA, 2023). The formulation of this policy was motivated by various factors, including the necessity for effective policy coordination and implementation, the decline in Nigeria's oil reserves, the issue of affordable electricity access in rural areas, the pressing need for restructuring the electricity industry, and the promotion of environmentally friendly energy technologies (IEA, 2023). REMP offers a comprehensive framework for the effective deployment of renewable energy sources in order to attain sustainable development objectives (Ley, 2015). The main objective of REMP is to address the need for a higher proportion of renewable electricity production in the country (IEA, 2023; FMPWH, 2017). Currently, renewable sources account for 13% of electricity generation, as of 2015 (IEA, 2023; FMPWH, 2017). The plan aims to increase this share to 23% by 2025 and further progress to 36% by 2030 (IEA, 2023). Additionally, the REMP seeks to enhance grid reliability and security within the nation (IEA, 2023). The primary objective of the REMP was to enhance the availability of electricity, aiming to raise the access rate from 42% in 2005 to 60% in 2015 and subsequently to 75% by 2025, encompassing both urban and rural regions (IEA, 2023).

Objectives of REMP

- Sustainable Development and Climate Change Mitigation: makes provision for access to clean and affordable energy particularly in rural and underserved areas, and to contribute to global efforts towards climate change mitigation.
- Diversification of Energy Sources: this involves the reduction of fossil fuel dependence and an increased share of renewable energy in the energy mix.
- Harnessing of Renewable Energy Resources: To effectively harness the vast resources such as solar, wind, biomass, hydropower, and geothermal, to maximise their contribution in the energy sector.
- Employment Opportunities: these opportunities include the manufacturing, installation, operation, and maintenance of renewable energy systems. REMP aims to provide these opportunities through the stimulation of investments and entrepreneurship in renewable energy sector.
- Technology Transfer and Indigenous Capability: to foster partnerships with the private sector and international organisations to facilitate the transfer of renewable energy knowledge and expertise thereby developing local expertise in Nigeria.

3. Renewable Energy Fund (REF)

The Renewable Energy Fund (REF) is a financial mechanism designed to provide support for the advancement of renewable energy initiatives in Nigeria (Oyedepo, 2012). The aim of this programme is to mitigate the financial obstacles encountered by developers, investors, and other relevant parties in the execution of renewable energy ventures (Emodi and Boo, 2015). This is achieved by offering financial aid and incentives, including accessible and enduring financing options, loans, grants, equity investments, and similar measures (FMPWH, 2016). The ultimate goal is to encourage the proliferation of renewable energy initiatives nationwide, thereby closing the financial disparity and attracting potential investors (Akuru and Okoro, 2014). The fund serves to support capacity-building endeavours, including workshops and other training initiatives, aimed at improving technical expertise and cultivating a proficient workforce within the nation (NESP, 2015). Additionally, it aids in advocating for favourable policies and regulations that foster the advancement of renewable energy (Sambo, 2016).

4. Feed-in Tariff (FiT) Program

The Feed-in Tariff (FiT) programme is a renewable energy support mechanism overseen by the National Electricity Regulatory Commission (NERC) (NERC, 2015). Its primary objective is to incentivize investment in the energy sector and promote the growth of renewable energy projects by offering assured compensation for the electricity produced (Emodi and Boo, 2015).

The aforementioned financial incentive is a mechanism that provides subsidies to mitigate the upfront expenses of renewable energy initiatives and effectively manages the inherent uncertainties associated with such projects (Ohunakin et al., 2014). Developers and investors engaged in renewable energy projects typically submit applications to the NERC to obtain a licence that qualifies them as renewable energy generators (NERC, 2015). Once approved, they are then granted long-term contracts with predetermined tariff rates for each unit of electricity generated and supplied to the grid (Akuru and Okoro, 2014). The specific tariff rate is contingent upon the type of renewable energy technology utilised, such as solar, wind, small hydropower, and biomass (Oyedepo, 2012). This facilitates the mitigation of the financial obstacles posed by substantial initial expenses and the restricted availability of affordable financing during the initial phases of such projects (Mas'ud et al., 2015).

In addition, the FiT programme plays a crucial role in fostering the growth of the domestic renewable energy sector. It achieves this by establishing a conducive framework that incentivizes the development of local manufacturing capabilities and supply chains for renewable energy components, including solar panels and similar materials (FMPWH, 2016). Consequently, this phenomenon generates employment prospects for the local population (Sambo, 2016).

In summary, the FiT programme has demonstrated its efficacy as a viable mechanism for facilitating the production of renewable energy and the generation of low-carbon electricity in numerous nations across the globe (REN21, 2020). Moreover, it has played a pivotal role in expediting the shift towards decarbonisation (IRENA, 2019).

2.10.6 Benefits of NZEBs: Nigeria's Perspective

Nigeria has yet to make significant progress towards attaining its net zero target by the year 2060 (United Nations, 2022). Literatures indicates that there are potential benefits to be derived from NZEBs in the region, given its abundant resources. The benefits mentioned are delineated in Figure 2.17 within the framework of the three (3) pillars of sustainability. This section provides a greater overview of the advantages associated with it.

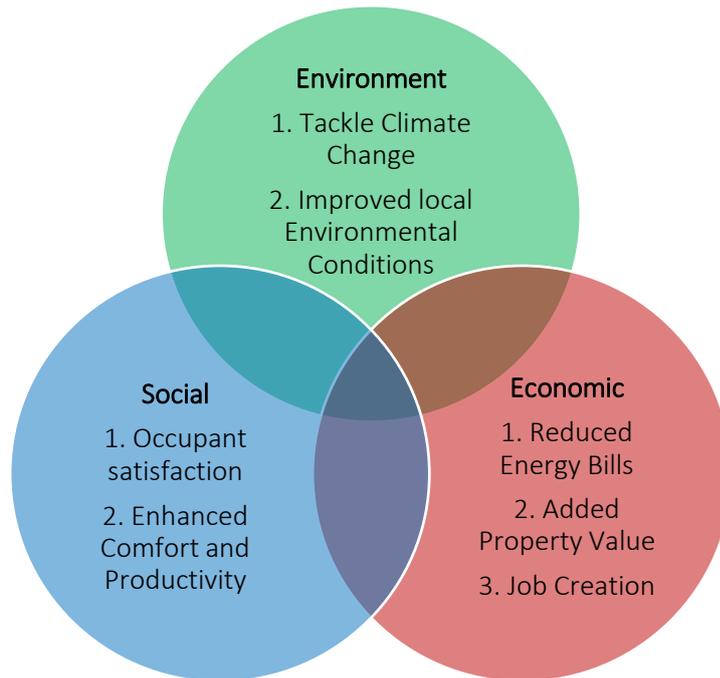


Figure 2.17: summary of potential benefits of NZEB adoption in Nigeria under the 3 pillars of sustainability

(Source: United Nations, 2017).

Table 2.17 shows a summary of the potential benefits to be derived from NZEBs in the region, given its abundant resources

Potential Benefits of NZEB Adoption in Nigeria

Occupants / Owners	Government / Policymakers	Developer
<ul style="list-style-type: none"> • Health and Well-being: one of the advantages of NZEBs is that it enhances the health and well-being of its occupants. • Increased Human Comfort: NZEBs mitigate heat transfer, thereby ensuring a cool indoor environment in hot climates and a warm indoor environment in colder climates. In addition, it offer enhanced visual and acoustic comfort, as well as a high standard of indoor air quality. • Cost Savings on Energy Bills and Revenue Generation: Utilises the absolute minimum amount of energy required to sustain households. • Eco-friendly Environment: Foster's an environmentally sustainable atmosphere by effectively mitigating GHG emissions within the built environment. • Immune to Power Outages: NZEBs incorporate renewable energy sources, such as solar panels, to mitigate the remaining energy requirements of buildings. This integration guarantees uninterrupted access to electricity even in the event of power outages, thereby achieving a state of energy self-sufficiency. 	<ul style="list-style-type: none"> • Reduced Pressure on National Power Grid and Reduced Power Shortage: NZEBs have the potential to mitigate excessive reliance on the national grid by autonomously producing energy from renewable sources. • Economic Growth: NZEB adoption leads to enhanced power sector performance that benefits businesses, increased investments in buildings, stimulates job creation etc. • Job Creation: provides opportunity for job creation within the sector such as design, construction, and maintenance of NZEB buildings. • Continental Leadership and Diplomacy: The position of the Nigerian government on NZEB establishes the country as a prominent figure in the adoption of sustainable practices within the region. • Public Health: Extensive adoption is expected to yield substantial reductions in air pollution, foster the creation of healthier living and working conditions, and ultimately improve the overall quality of life throughout the nation. • Climate Change Mitigation and The Paris Agreement: Its adoption contributes to assisting the Nigerian government in achieving its SDGs. 	<ul style="list-style-type: none"> • Added Value to Property: While NZEBs are still a relatively new concept with limited awareness among Nigerian clients currently, their superior quality and advantages are expected to gain traction in the Nigerian Property market over time. Globally, NZEBs are highly attractive to buyers and renters due to long-term cost savings, environmental benefits, adoption of sustainable practices, and assurance amidst evolving energy policies. This is likely to lead to increased property values, faster sales, and better access to green financing for NZEB developers in Nigeria as well. • Access to Incentives: To facilitate the widespread implementation of NZEBs, governments collaborate with the private sector and international organisations to offer various incentives, including grants, loans, tax incentives, and technical support, to individuals or organisations engaged in NZEB projects. Through the implementation of this scheme, developers have the potential to mitigate certain barriers, such as limited capital for the project, while simultaneously enhancing productivity and profitability.

Figure 2.18: Potential benefits of NZEB adoption in Nigeria

(Sources: Ochedi and Taki, 2022; IMF, 2018, United Nations, 2017)

Figure 2.18 shows the potential benefits of NZEBs in Nigeria for occupants / owners, government / policymakers, and developers.

2.10.7 Key Barriers & Drivers to achieving NZEB in Nigeria

Barriers

1. **Lack of Awareness and Limited Knowledge:** According to Ochedi and Taki (2022), the concept of NZEB is not a popular knowledge amongst Nigerians. There is a lack of awareness and limited knowledge about NZEB amongst stakeholders including building professionals and policy makers (Ochedi and Taki, 2022). Homeowners most especially are not aware of the potential benefits such as its potential energy savings, improved indoor environmental quality (IEQ), and reduced environmental impact. The popularity of NZEB amongst homeowners would create a market for developers and building professionals which will in turn accelerate the adoption of NZEB.
2. **Socio-cultural Factors:** The perception of energy-efficiency amongst the people is a major factor in the adoption of NZEB (Oyalowo, Ohiro and Oginni, 2020; Wuni, Shen and Osei-Kyei, 2019). As people are not aware of the potential benefits of energy-efficiency, they are most

likely to resist its adoption. Amongst stakeholders in the building industry for instance, there is a display of nonchalance towards energy-efficiency despite calls to transition to a more sustainable approach in the industry (Abdullahi, *et al.*, 2017). This is a major barrier. Furthermore, cultural beliefs in building design can hinder the widespread adoption of NZEB (Abdullahi, *et al.*, 2017; Oyalowo, Ohiro and Oginni, 2020). It is therefore imperative that the government raise the level of awareness to educate the public on the long-term benefits such as energy savings, human comfort, and environmental impact. Also, local communities should be placed at the heart of the design and construction process by understanding their concerns and incorporating relevant cultural elements in the NZEB design. This will give the local communities a sense of belonging and ownership, and in turn, enable the adoption of NZEB practice in Nigeria.

3. **High Upfront Cost and Limited Financial Incentives:** The cost of energy-efficient materials, technologies, and renewable energy systems as well as the lack of financial incentives such as subsidies, grants etc is a major barrier to NZEB adoption in Nigeria as homeowners and developers might find it difficult to fund NZEB projects (Abdullahi, *et al.*, 2017; Oyalowo, Ohiro and Oginni , 2020; Wells, Rismanchi and Aye , 2018). If governments and financial institutions offer financial incentives such as grants, low-interest loans, tax breaks etc, this would make the NZEB market more attractive for homeowners, developers, and potential investors.
4. **Limited Access to Technology and Building Materials:** In Nigeria, there is a limited availability of NZEB technologies and building materials. The cost of importation of some specialised NZEB materials can be ridiculously high therefore homeowners and developers might lack interest in forging ahead with NZEB projects (Geissler, Susanne, Österreicher and Macharm, 2018). If provisions are made for the manufacture and distribution of these technologies and building materials locally, this gap will be significantly bridged.
5. **Poor Energy Infrastructure:** Nigeria is currently confronted with an energy crisis within its power sector (Ley, 2015; WAPP, 2021). This is a major challenge for the adoption of NZEB, as NZEB relies heavily on a stable and consistent power supply.
6. **Government:** Governments of nations should take the lead in the journey towards net-zero. The Nigerian government has shown lots of interest in transitioning to net-zero through series of policies and conventions it is signatory to (Iwuagwu and Onyegiri, 2019). However, it has failed to take a robust approach by prioritising this (Oyalowo, Ohiro and Oginni, 2020; Iwuagwu and Onyegiri, 2019). This is a major barrier. For example, the recent introduction of the Nigerian Building Energy Efficiency Code (NBEEC) – the first energy standard in the

country, is yet to see a widespread adoption due to several factors that is the responsibility of the government (Ochedi and Taki, 2022).

7. **Lack of Expertise:** The design and construction of NZEB requires a specialised technical knowledge and expertise in energy-efficient building design, renewable energy systems and NZEB technologies (WorldGBC, 2023). There is a limited number of building professionals with this level of expertise in the country (Nwaiwu, 2021; FMPWH, 2017). This is a significant barrier. To help bridge this gap in expertise, it is important the government invest heavily in capacity building initiatives that will train a wide range of building professionals on NZEB design and construction. This will significantly increase the pool of energy-efficient building experts.
8. **Shortage of Reliable Data:** A reliable data on energy consumption in residential buildings is crucial to ascertain the baseline case in the country (Nematchoua, *et al.*, 2019; Arup, 2017a). Having an accurate data will help understand the current energy usage patterns in residential buildings. Currently, there is a shortage of reliable data on energy consumption in residential buildings (FMPWH, 2017). This is a major challenge as the progress of NZEB becomes difficult to track and measure as well as identifying areas for improvement. Furthermore, a reliable data is crucial for informing the development of effective policies and regulatory frameworks, setting realistic targets, and knowledge sharing and best practices. This challenge is partly due to individual electricity generation using diesel and petrol and poor metering system. This makes the collection of data difficult. Chinedu Nebo, the former minister of Power estimated that 55% of Nigerian electricity users are not metered (FMPWH, 2017).

Drivers

1. **Public Awareness:** Public awareness campaign is key to achieving NZEB in Nigeria (World Bank, 2017; KPMG, 2022a). There should be an increased awareness on the benefits of NZEB such as improved human comfort, potential cost savings, and environmental impacts. The more knowledge individuals and organisations have about NZEB, the more interest they will develop in acquiring NZEB homes, advocating for policies and regulations, and making an informed decision for the design of their homes (WorldGBC, 2023). This will create an interesting market and increase the demand of NZEB homes. It will also address the social-cultural barrier by normalising sustainable building practices, leading to wider acceptance across the country. It is important to develop a strategic communication channel such as community outreach programs, multimedia campaigns, and education's curriculum, to reach the targeted population across the country.

2. **Capacity Building:** This is a key driver in an emerging market like Nigeria. According to the World's Bank (WB) report, the development of NZEB knowledge, skills, and expertise of building professionals through initiatives such as trainings, and workshops will accelerate the transition to low carbon buildings (KPMG, 2022a; World Bank, 2017). These programs will enhance the understanding of NZEB practices such as its principles, design strategies, energy modelling, energy-efficient building systems and renewable energy technologies. The capacity building programs should also extend to policymakers and regulatory authorities to enable them to make informed decisions on NZEB policies, building codes, and standards.

3. **Incentives:** incentives are one of the most influential drivers of NZEB (Aliyu, Modu and Tan, 2018). It could be in the form of finance or technical assistance. Policy makers should make provision for tax credits, grants, subsidies, low-interest loans, etc to homeowners and developers who undergo NZEB projects. An enabling environment should also be created to encourage financial institutions to do same. This would reduce the upfront cost and provide financial benefits for homeowners and developers therefore, making the NZEB market economically viable and attractive.

Another incentive can come in the form of technical assistance. Technical assistance should be given to those undergoing NZEB projects or living in NZEB homes. This could be in the form of design assistance or energy audits. The provision of technical assistance would ease the complexities in the design and construction of NZEB projects, therefore, bridging the technical barrier (Aliyu, Modu and Tan, 2018).

4. **Local Manufacture of NZEB Materials and Technology:** The manufacture of NZEB materials and technology locally is crucial in the delivery of NZEBs (Oree and Anatah, 2017). By manufacturing NZEB materials locally, the pressure on importation of these materials is significantly reduced, therefore making these materials readily available to homeowners and developers for the construction and maintenance of NZEBs (Oree and Anatah, 2017; Aliyu, Modu and Tan, 2018; Enteria, Awbi and Yoshino, 2015). It also leads to significant reduction in the cost of importation, transportation, carbon footprint resulting from the transportation of these material thereby making it more affordable, financially sustainable, and environmentally responsible.

Furthermore, as NZEB design is context based, it is imperative the materials are designed to address the specific needs of the local market. Local manufactures will have a better understanding of the specific needs of the local context, including the cultural and construction practices, and the climatic conditions, resulting in designs that are more effective for NZEBs.

In conclusion, the local manufacture of NZEBs will strengthen the supply chain and stimulate the wider adoption of NZEBs.

2.11 An Overview of Green Building Standards: BREEAM, LEED, Passivhaus, EDGE and NBEEC

Justification for Selection: The Building Research Establishment's Environmental Assessment Method (BREEAM) and Leadership in Energy and Environmental Design (LEED) are widely recognised as the leading green building standards in the field of sustainable construction and environmental assessment (Ade and Rehm, 2020). Passivhaus is widely recognised as a prominent energy standard that enjoys international acclaim (Schnieders et al., 2015). Furthermore, the International Finance Corporation (IFC) has developed an initiative called Excellence in Design for Greater Efficiencies (EDGE), which is specifically aimed at addressing the needs of emerging markets (IFC, 2021). The Nigerian Building Energy Efficiency Code (NBEEC) is a recently implemented energy standard specifically designed to suit the unique circumstances of Nigeria (FMPWH, 2017). A thorough understanding of these standards is crucial in the development of a strategic plan for attaining NZEBs (Marszal et al., 2011).

2.11.1 BREEAM

The Building Research Establishment (BRE), a research organisation based in the United Kingdom, developed BREEAM between 1980 and 1990 (CIBSE, 2020). BREEAM is recognised as the world's inaugural green building rating system (BREEAM, 2018). Originally, BREEAM was exclusively employed within the United Kingdom and limited to a particular category of buildings (BREEAM, 2018). Nevertheless, the field has undergone significant developments over time, resulting in an expansion of its purview to encompass a wide range of geographical locations and building typologies (BREEAM, 2018). The green building standard in question has achieved international recognition and has served as a blueprint for the development of various other green building rating systems (Palmer and Armitage, 2014).

The objectives of BREEAM include ensuring that the best environmental practice is incorporated in buildings, raising awareness about the benefits of environmentally sustainable buildings to the environment, providing market presence to low environmental impact buildings, challenging the status quo in the industry to be innovative in terms of providing solutions that minimize the environmental impact of buildings, and allowing organizations to demonstrate progress towards corporate environmental objectives (Palmer and Armitage, 2014; BREEAM, 2018).

BREEAM assessment process involves several stages:

1. Pre-assessment: This stage allows for the obtaining of an initial assessment of the building's environmental performance by the project teams to identify areas for improvement (BREEAM, 2018). This stage is optional.
2. Design stage assessment: This occurs during the design phase of the building. At this stage, information of the building's design is provided by the project team. This information provided is then assessed against the BREEAM criteria (BREEAM, 2023).
3. Post-construction assessment: This occurs after the building is constructed. At this stage, a post-construction assessment is carried out to verify and evaluate the building's actual sustainability performance (BREEAM, 2023).
4. Certification: Depending on the building's overall performance, a BREEAM certification rating ranging from Pass, Good, Very Good, Excellent, and Outstanding is awarded at this stage, following the result of the post-construction assessment. As BREEAM requires a minimum of 30% of the credits to be certified, buildings with less than 30% are "unclassified" therefore cannot be certified (BREEAM, 2023). Table 5

Table 6: BREEAM Rating System

(Source: BREEAM, 2023)

BREEAM Rating	Score (%)
Outstanding	85%
Excellent	70%
Very good	55%
Good	45%
Pass	31%
Unclassified	<30%

The criteria for certification include management strategies, primary energy consumption and CO2 reduction, health and well-being: Both indoor and outdoor quality, transport: CO2 production concerning material transport, water consumption, materials used in the project's life cycle, along with their environmental impact, waste production and management, land use and ecology of the

site, emissions of polluting elements, along with sound and light, additional credits for particularly remarkable means of innovation included in the project (BREEAM, 2023).

The benefits of BREEAM certification include:

1. Environmental: BREEAM encourages carbon emission reduction, energy consumption, and water usage, as well as biodiversity and ecosystem protection and enhancement (Ade and Rehm, 2020).
2. Economic: There's a higher market value for BREEAM-certified buildings compared to conventional buildings (Fuerst and McAllister, 2011). Furthermore, BREEAM makes provision for cost effective design and construction practices that results in long-term operational savings through reduced energy and water bills (Schwartz and Raslan, 2013).
3. Social: By considering factors such as thermal, visual, and aural comfort, BREEAM promotes overall human comfort, and productivity (Altomonte and Schiavon, 2013).

Disadvantages of BREEAM

1. Cost Implications: Additional cost might be incurred to achieve higher certification levels, such as Excellent or Outstanding. This can discourage developers and potential investors and limit its widespread adoption (Dwaikat and Ali, 2016).
2. Checklist Compliance: A significant emphasis is placed on meeting specific checklist requirements and performance targets to be BREEAM-certified. Although this approach ensures a standardised assessment, critics argue that this will promote a box-ticking mentality which is only concerned about meeting the minimum requirements rather than driving genuine sustainability and innovation (Schweber, 2013).
3. Complexity: The BREEAM certification process can be time-consuming due to extensive documentations, data collection, and analysis, therefore making it a complex process (Ade and Rehm, 2020).

In conclusion, BREEAM is a comprehensive environmental assessment method and certification with a flexible and adaptable framework (to various building types) that encourages sustainable building practices.

2.11.2 LEED

The sustainability rating system known as Leadership in Energy and Environmental Design (LEED) was developed by the US Green Building Council (USGBC) (Baumann, Reiser and Schafer, 2004; He, *et al.*, 2018). The green building certification system is widely acknowledged on the global stage, with a presence spanning across more than 165 countries and continuing to expand (Doan *et al.*, 2017). The

LEED certification programme places emphasis on the environmental quality of buildings and the development of neighbourhoods, utilising a set of performance-based criteria. A point-based system is employed to evaluate and assess the design and construction of green buildings. Table 11. The level of certification achieved, ranging from Certified to Silver, Gold, and Platinum, is directly proportional to the number of points awarded. Table 12.

The 7 Objectives of LEED are reversing the contribution to climate change, improving the health and well-being of the individual, protecting and restoring water resources, protecting and restoring the diversity of species and the ecosystem, promoting sustainable and regenerative material loops, establishing a more ecological economy, and improving social justice, environmental awareness, and quality of life (He, *et al.*, 2018).

The LEED certification process involves various stages:

1. Project Registration: This is the first stage of the LEED certification process. At this stage, the project team is required to register the building with the USGBC and select the appropriate LEED rating system based on the building type and project goals (USGBC, 2021).
2. Design and Documentation: The buildings design and relevant documentation (such as calculations and performance data) that demonstrates compliance with the applicable LEED criteria is expected to be submitted by the project team at this stage (Wu et al., 2016).
3. Application and Review: At this stage, an application is made by the project team to the USGBC for review. The USGBC reviews the application by assessing the project's compliance and assigns points based on the LEED criteria. Further inquiries or clarification might be required by the USGBC from the project team if need be (Neufeld et al., 2018).
4. Certification: Depending on the total number of points earned at the application and review stage, the project is awarded a LEED certification level ranging from Certified, Silver, Gold, to Platinum (Owens et al., 2018).

The key features and benefits of LEED certification include:

1. Energy Efficiency: LEED promotes significant reduction in energy consumption and GHG emissions through energy-efficient strategies (Scofield, 2013).
2. Water Conservation: LEED encourages water efficiency using strategies such as rainwater harvesting, water-efficient landscaping, low-flow fixtures, etc. (Hwang and Tan, 2012).
3. Sustainable Materials: LEED promotes the adoption of environmentally friendly building materials, including locally manufactured (Wu et al., 2016).

4. Indoor Environmental Quality: For a building to be LEED-certified, measures such as daylighting, proper ventilation, and low-emitting materials are required to provide overall human comfort (MacNaughton et al., 2016).
5. Sustainable Building Sites: This involves the promotion of sustainable building sites such as alternative transportation option, reduction of light pollution, and protection of the ecosystems (Owens et al., 2018).
6. Innovation and Design: Projects that implement new and creative approaches to sustainability are well rewarded under the LEED certification. This is a strategy employed to encourage innovation in building design and construction (Neufeld, Luo and Chen, 2018).

Disadvantages of LEED

Although LEED is widely recognised and adopted, it is not without criticism. Some of the disadvantages associated with LEED include:

1. Complexity: As seen with BREEAM, the certification process of LEED can be time-consuming as it involves extensive documentation, data collection, and analysis, therefore making it a complex process (Ade and Rehm, 2020).
2. Focus on Design and Construction: Although LEED considers some aspects of building operation and maintenance, there isn't a comprehensive guidance on ongoing performance or post-occupancy behaviour, therefore resulting to effectively designed building but less performing as intended to (Newsham et al., 2009).
3. Cost Intensive: Organisations with limited resources and small-scale projects most especially may encounter administrative barriers associated with obtaining LEED certification. Furthermore, the higher the level of certification such as Gold or Platinum attracts additional expenses due to advanced technologies and design features (Dwaikat and Ali, 2016).
4. Limited Emphasis on Health and Well-being: Critics of LEED argue that the rating system does not prioritise health and well-being in comparison to other rating system such as WELL building standard (Worden *et al.*, 2020).
5. One-Size-Fits-All Approach: LEED is not flexible enough to accommodate factors such as local climate, specific building typologies, and culture due to its prescriptive nature and standardised credit requirements. This rating system is not practical in Nigeria (Awadh, 2017).
6. Limited Focus on Embodied Carbon: It is more focused on operational energy, while giving less attention to embodied energy (Röck *et al.*, 2020). To address the whole life cycle of buildings, it is imperative to adopt a wholistic approach.

Table 6: LEED Rating System point-based system
(Source: Scofield, 2013)

Category	Point
1. Sustainable site	13 points
2. Water efficiency	6 points
3. Energy and Atmosphere	17 points
4. Material and Resources	13 points
5. Indoor Environmental Quality	15 points
6. Innovation and design process	5 points
Total	69 points

Table 6 shows LEED Rating System point-based system

Table 7: LEED Rating System level of Certification

(Source: Scofield, 2013)

Certification	Points
LEED-Certified	26-32
LEED-Silver	33-38
LEED-Gold	39-51
LEED-Platinum	52-69

Table 7 shows LEED Rating System level of certification.

In conclusion, LEED has established a notable presence in the environmentally conscious construction industry by virtue of its rigorous certification standards. Moreover, by virtue of its extensive reach, it has demonstrated its dedication to advancing sustainable building practises globally.

2.11.3 Passivhaus (Passive House Standard)

Justification for selection: Several previously examined scholarly works have advocated for the adoption of a passive strategy as a viable approach to accomplishing decarbonisation in buildings (Aflaki, *et al.*, 2015; Doctor-Pingel, Lavocat and Bhavaraju, 2017; Nematchoua, *et al.*, 2020). The literature reviewed in these studies presents a compelling argument for the utilisation of passive design strategies as the most sustainable approach. The Passivhaus standard is characterised by its adoption of passive design strategies, making it a prominent benchmark for building energy efficiency (Passivhaus, 2013). Moreover, the Passivhaus standard demonstrates its adaptability to diverse climate zones and building typologies, making it feasible for implementation in tropical countries such as Nigeria.

Overview

Passivhaus, alternatively referred to as Passive House, is a prominent global standard for energy performance in architectural design that first emerged in Germany during the 1990s (Feist *et al.*, 2005). According to the findings of BRE (2021), the central objective of Passivhaus is to achieve a substantial reduction in the demand for space heating and cooling in buildings, resulting in the creation of ultra-low energy structures that offer exceptional levels of human comfort. The achievement of this outcome is facilitated by the integration of energy-efficient design principles, meticulous construction techniques, and advanced building technologies (Schnieders and Hermelink, 2016). In addition, the design of the aforementioned demonstrates meticulous attention to detail and adherence to the principles established by the Passive House Institute (PHI) in Germany (Passivhaus, 2013). The Passivhaus standard, in comparison to other green building standards, offers a greater degree of design flexibility, provided that the energy balance within buildings is successfully attained (Müller and Berker, 2013).

Passivhaus is guided by five main principles:

- 1. Continuous Insulation (Low U Value ≤ 0.15):** The internal temperature of the building is maintained with continuous insulation of the building envelope (Müller and Berker, 2013). Therefore, during winter the heat loss is minimized and during the summer the heat gain is minimised. This allows for comfortable interior surface temperature.

The Passivhaus standard requires all thermal elements to have a very good U value (IPHA, 2021).. The absolute value adopted for opaque elements will vary according to the building's context (e.g., location, form etc) (McLeod, Mead, Kym and Standen, 2012).

The recommended limits are walls, floors, and roofs = $\leq 0.15 \text{ W/m}^2\text{K}$, and complete window installation = $\leq 0.85 \text{ W/m}^2\text{K}$ (Kym and Standen, 2012).

- 2. Continuous Air Seal Layers (Air Tightness):** Continuous air seal prevents air leakages, reduces possible moisture damage to building envelope, reduce humidity during the summer and reduce heat loss during winter (Kym and Standen, 2012). To reduce the heating or cooling demand and prevent moisture laden air from infiltrating the fabric, the building must have very good airtightness levels. The air tightness of a Passivhaus building is defined by an n50 or q50 test measurement which combines both under and over pressurisation tests (Kym. and Standen, 2012). The air tightness testing convention differs, as some regions measures the air leakage (should not be greater than 0.6 air changes per hour - 0.6 ac/h @50 Pa), some measures the air infiltration ($\text{m}^3/\text{m}^2\text{h}$ @ 50 Pa) of the exposed building fabric. (McLeod, Mead, Kym and Standen, 2012).
- 3. Eliminate Thermal Bridges:** Junctions and connections provide a thermally conductive route for heat loss (IPHA, 2021). External insulation and the strategic positioning of insulation helps in the reduction of thermal bridges at junctions and connection. A psi value of $\leq 0.01 \text{ W/mK}$ is the Passivhaus standard for thermal bridges (Kym and Standen, 2012).
- 4. High Performance Glazing (Passive House Certified Windows):** High performance glazing with Passive House Certified Windows minimizes heat flow in buildings and increase surface temperature. (McLeod, Mead, Kym and Standen, 2012).
- 5. Mechanical Ventilation with Heat Recovery System (MVHR):** An MVHR system extracts air from certain rooms (e.g., kitchens and bathrooms) and supplies fresh air to other rooms (IPHA, 2021). The air that is extracted from these rooms is warm indoor air which passes through a heat exchanger giving up the warmth from that air to the incoming fresh outdoor air (McLeod, Mead, Kym and Standen, 2012).

The benefits of Passivhaus include:

- 1. Energy Efficiency:** In comparison to conventional buildings, Passivhaus-certified buildings typically consume up to 90% less energy for heating and cooling, therefore resulting to a significant reduction in energy cost and carbon emission (Passivhaus Trust, 2023).
- 2. Thermal Comfort:** Passivhaus-certified buildings offer a high level of thermal comfort by effectively regulating indoor temperatures throughout the year, while minimising fluctuations in proximity to windows or walls (Schnieders et al., 2020).

3. **Indoor Air Quality:** Passivhaus-certified buildings typically have a constant supply of filtered fresh air, through the mechanical ventilation system, leading to an improved human comfort for building occupants (Moreno-Rangel et al., 2020).
4. **Durability and Resilience:** Passivhaus construction techniques, such as the implementation of airtightness and moisture control measures, play a significant role in enhancing the durability and resilience of buildings (Passive House Institute, 2022). These measures effectively mitigate the risks associated with moisture infiltration, condensation, and the resulting structural damage.
5. **Futureproofing:** One of the many benefits of Passivhaus is the buffer it provides for homeowners and building occupants against rising energy costs and potential energy supply disruptions due to its highly energy-efficient design that makes it less dependent on fossil fuels for heating and cooling (IPHA, 2021).

Disadvantages of Passivhaus include upfront costs, design limitations, climate-dependent performance, retrofitting existing buildings, and availability of skilled professionals (McLeod, Hopfe and Kwan, 2013).

In conclusion, Passivhaus has contributed significantly to the decarbonisation of the building sector, and in the process becoming a global movement amongst building professionals and organisations who had embraced its principals.

2.11.4 EDGE

Justification for Selection: Geographical location has an inherent influence on the concept of sustainability, which emphasises the significance of customising comfort standards to particular regions while considering their distinct climatic conditions and varying levels of economic development (Nguyen and Reiter, 2017). The gap in question has been effectively addressed by the Excellence in Design for Greater Efficiencies (EDGE) initiative. The EDGE standard and software application have been developed specifically for "Emerging Economies" with the aim of promoting innovation in green building practises (IFC, 2023). The study is situated within the scope of an emerging economy, thus necessitating an understanding of this particular context.

Overview

The EDGE tool was developed by the International Finance Corporation (IFC) – a member of the World Bank Group, in partnership with the World Green Building Council (WGBC) (World Bank, 2017; IFC, 2019). Launched commercially in 2015, it is aimed at identifying low-cost sustainable

opportunities for building green based on local climate, building type, and occupant behaviour in emerging market (IFC, 2023). It is a simplified and affordable green building standard that focuses on quantified energy and water savings, embodied energy in materials, and greenhouse gas emission reductions – a 20% efficiency in energy, water, and embodied energy in materials (IFC, 2019). EGDE can be adopted for the entire building portfolio and provides a pathway towards building to net zero carbon standards.

EDGE tool captures the capital costs and projected operational savings for various measures at the early conceptual stage (WorldGBC, 2023). It is intended for use by building professionals rather than green building experts and provides measurable ways for builders to optimize their designs and can be applied through all stages of a project's life cycle from the conceptual stage to on-site decision-making.

The EDGE software shows how the application of practical energy and water-saving options improves building performance at little or no cost (IFC, 2023). This enables easy modelling of future performance without sacrificing design integrity and gives a clear picture to the most economically viable path to achieving sustainability (WorldGBC, 2023).

EDGE views sustainability from a financial standpoint and adopts a quantitative approach through sharing local climate data and cost. It proves the business case for building green and unlocks financial investment by providing developers the opportunity to gain a competitive advantage in the market (IFC, 2023). It is changing markets around the world with well over \$1 billion worth of project globally being certified monthly and unlocks collaboration by bringing together industry players/stakeholders (green building users, designers, developers, and financiers) and provides a new paradigm for the future (WorldGBC, 2023; IFC, 2019; World Bank, 2017).

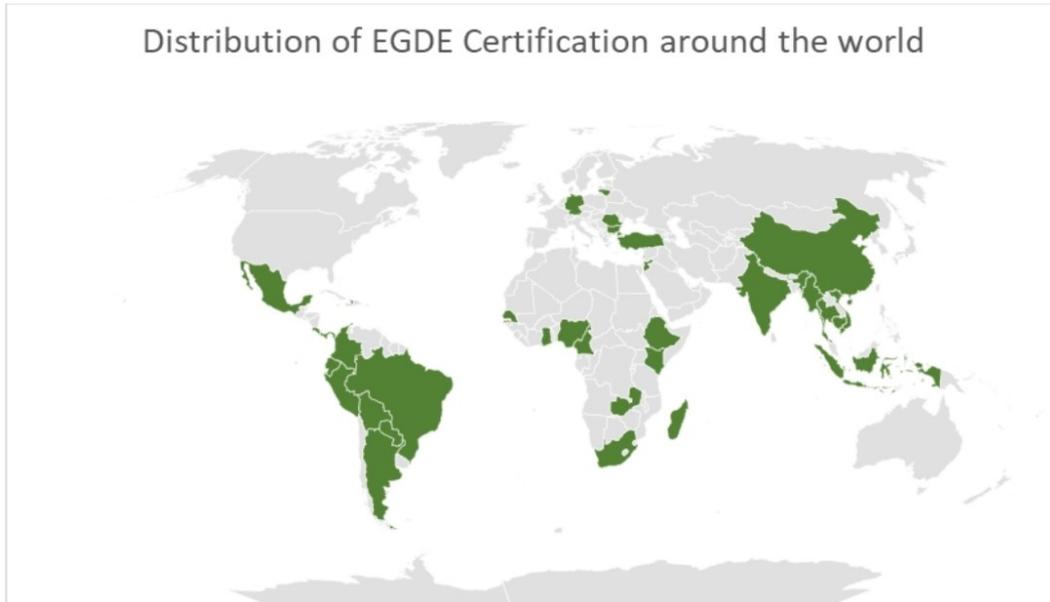


Figure 2.19: EDGE certified buildings around the world.

(Source: MITSIDI PROJECTOS, 2022)

Figure 2.19 shows the regions with EDGE Certified buildings around the world in green. A high concentration of EDGE Certified buildings can be seen in the South American region.

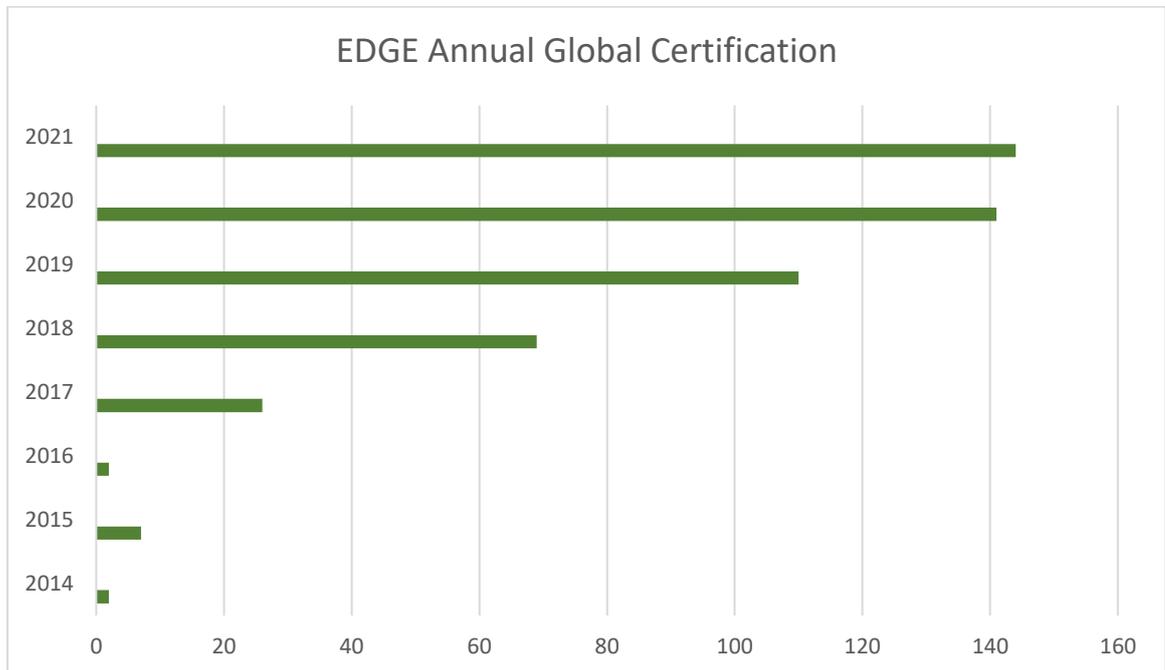


Figure 2.20: EDGE Annual Global Certification

(Source: MITSIDI PROJECTOS, 2022)

The EDGE certification has seen a steady increase globally in the past couple of years. It has successfully penetrated global markets such as Colombia, South Africa, India among other (MITSIDI PROJECTOS, 2022). Figure 2.20 shows the global annual growth of EDGE Certification. From the years

2019, EDGE has certified over 100 buildings annually. A substantial growth was seen despite the COVID-19 pandemic in 2020 and 2021.

There are three (3) stages of EDGE certification.

1. EDGE Certified
2. EDGE Advanced
3. EDGE Zero Carbon



Figure 2.21: Three (3) stages of EDGE Certification

(Source: MITSIDI PROYECTOS, 2022)

Figure 2.21 shows the three stages of EDGE certification.

EDGE Certified

For EDGE Certified, new, existing, or refurbished buildings must exceed business as usual efficiency by 20% in energy, water, and embodied energy in materials for new construction (IFC, 2019).

Figure 2.18 shows the top 19 countries with the most EDGE certified buildings. The South American continent clearly dominates this category. As of 2022, Colombia is the country with the highest level of EDGE certified buildings with 118 buildings. Vietnam, Indonesia, and Mexico also have a strong EDGE presence with 49, 48 and 40 buildings respectively. Nigeria is ranked 14 on the list with 8 buildings. Although Colombia dominates this category, Indonesia has more EDGE Advanced certified buildings. Meaning the region has more EDGE Certified buildings with 40% energy savings compared to other regions. Figure 2.22.

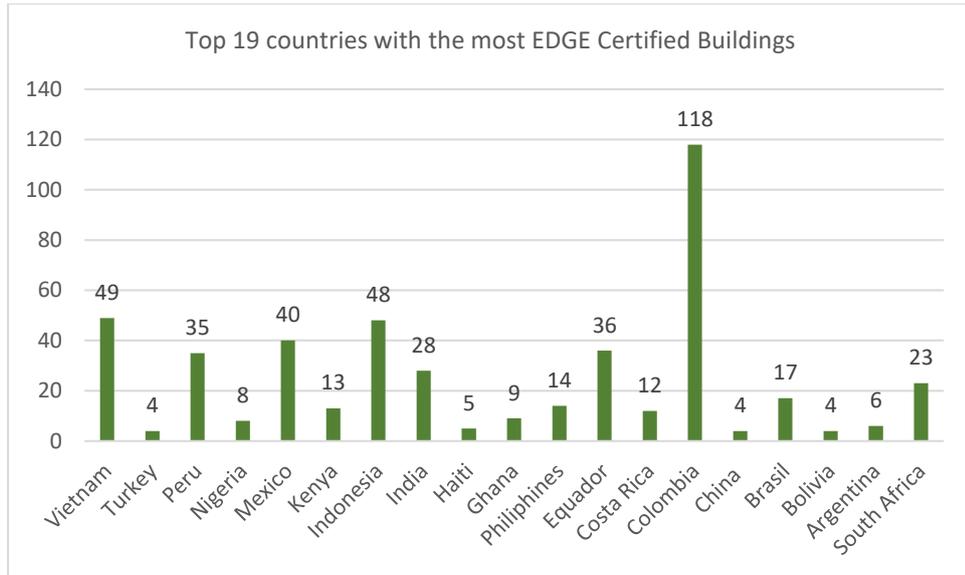


Figure 2.22: Countries with the most EDGE Certified Buildings

(Source: MITSIDI PROYECTOS, 2022)

EDGE Advanced

EDGE Advanced is obtained for buildings which attains 40% energy efficiency (IFC, 2019). Figure 2.23 shows that Indonesia takes the lead for the EDGE Advanced category with 21 buildings, therefore Indonesia is the country with the most buildings which has attained 40% energy efficiency for EDGE standard. Colombia ranks 2nd place with 14 buildings, Mexico, and India in joint 3rd with 11 buildings and Vietnam follows with 10 buildings. Nigeria is jointly ranked 10th on the list with 4 buildings.

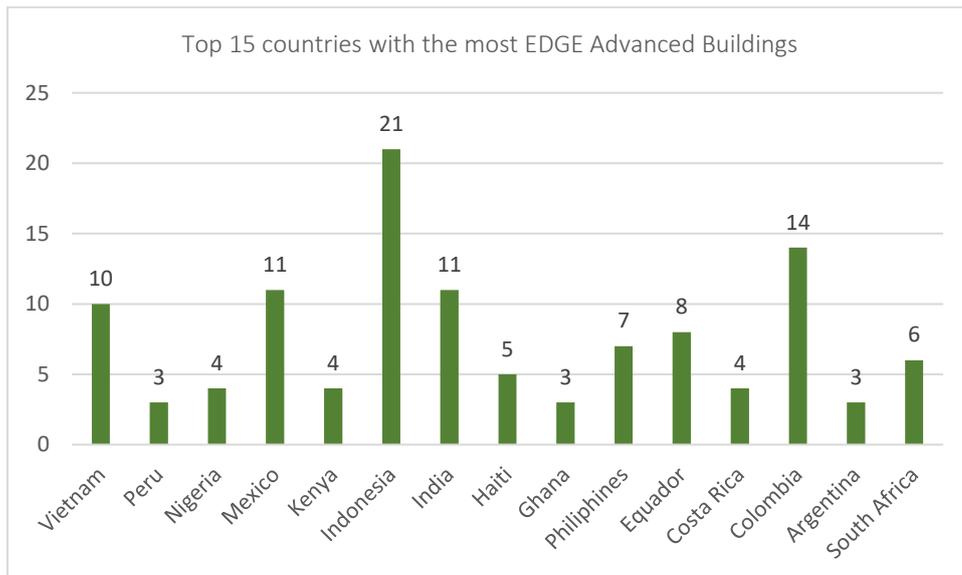


Figure 2.23: Countries with the most EDGE Advanced Buildings

(Source: MITSIDI PROJECTOS, 2022)

EDGE Zero Carbon

EDGE Zero Carbon building is an EDGE Advanced building which uses 100% renewable energy or purchases carbon offsets. Only 4 countries (Mexico, Bulgaria, India, and the Philippines) in the world have an EDGE Zero Carbon certified building, with one in each country (MITSIDI PROJECTOS, 2022). It is important to note that the EDGE Zero Carbon certification is relatively new.

Key Features of EDGE

1. **Software Application:** The EDGE software is a user-friendly online software application which can be used by architects, engineers, and developers to optimise the design of buildings. The potential resource savings and financial viability of various building design options can be evaluated by simply inputting its building data. The software application continues to evolve continues to evolve, incorporating feedback and updates to align with the latest industry standards and practices (IFC, 2023).
2. **Resource Efficiency Categories:** EDGE focuses on three primary categories of resource efficiency: Energy, Water, and Materials. The software application enables the quantification of resource savings resulting from the implementation of measures in these three distinct categories. This functionality empowers users to effectively compare various design scenarios and make well-informed decisions (EDGE, 2024a).
3. **Minimum Standard:** To meet the criteria for EDGE certification, a building must attain a minimum of 20% reduction in embodied energy in materials when compared to a baseline building. The determination of this baseline building is based on the prevailing local building codes and standards (EDGE, 2024b).
4. **Local Climate Considerations:** The EDGE software considers the local climate and environmental conditions of the project location and provides climate-specific recommendations and strategies to optimise the building's performance in terms of energy efficiency, water conservation, and materials usage (Passive House Institute, 2022).
5. **Cost Optimisation:** EDGE goes beyond environmental sustainability by integrating the financial viability of a given project. It offers valuable insights into the supplementary initial expenses associated with the implementation of resource-efficient measures, as well as the duration required for these investments to be recouped. This tool assists users in identifying solutions that strike a balance between environmental benefits and financial viability, thereby promoting cost-effectiveness (WorldGBC, 2023).

6. EDGE Certification: Once a project meets the required resource savings threshold, it receives EDGE certification (EDGE, 2024c).

Benefits of EDGE

1. Environmental Benefits: EDGE promotes resource-efficient design strategies by reducing energy consumption, water usage, and the embodied energy in buildings. As a result of this, EDGE contributes to a lower carbon footprint, and a sustainable built environment (IFC, 2023).
2. Cost Savings: The EDGE programme emphasises the evaluation of the financial feasibility of a proposed project, with the aim of encouraging the adoption of cost-effective design choices that can lead to reduced operational building costs. The EDGE software is capable of identifying design options that lead to substantial resource savings, while also offering a reasonable payback period. This ensures that the financial benefits align with the environmental benefits (EDGE, 2024a).
3. Market Differentiation: EDGE-certified buildings have a much higher value in the market therefore is sort after by investors, and tenants who values sustainability and savings on operational cost (WorldGBC, 2023).
4. Supports Emerging Markets: With a growing need for sustainable and affordable housing in emerging markets particularly in Nigeria, EDGE becomes even more relevant in this region as it bridges the gap between sustainability and affordability (Oyekanmi *et al.*, 2022).

Disadvantages of EDGE:

Limited Professionals: Although EDGE experts and assessors – trained to design and conduct assessment respectively - is fast growing globally, some regions like Nigeria have a shortage of these professionals (IFC, 2023). This is a significant barrier to the widespread adoption and implementation of the EDGE certification.

In conclusion, EDGE is an innovative solution to building sustainability and affordability in emerging markets. As Nigeria is in a housing crisis and urgently needs more homes sustainably and at an affordable price, EDGE presents an ideal solution. The adoption of EDGE in the country should therefore be encouraged.

2.11.5 Nigeran Building Energy Efficiency Code (NBEEC)

The power sector in Nigeria is currently confronted with a substantial deficit in electricity supply and challenges pertaining to energy efficiency within buildings (Emodi and Yusuf, 2015; Oyedepo, 2012).

This led to the development of the Nigerian Building Energy Efficiency Code (NBEEC) by the Federal Ministry of Power, Works, and Housing (BEEC, 2017). NBEEC is a set of guidelines and standards developed to promote energy efficiency in the design, construction, and operation of buildings in Nigeria (Oyekanmi et al., 2022). The primary objective of the code is to mitigate energy consumption, decrease GHG emissions, and improve the overall sustainability of the built environment in Nigeria (BEEC, 2017).

NBEEC establishes the minimal energy threshold necessary to attain energy efficiency in buildings, promoting the creation of thermally comfortable and healthy built environments (Olaniyan et al., 2018). When employed in an efficient manner, the implementation of NBEEC has the potential to achieve a reduction of up to 40% in the existing energy consumption levels of structures (BEEC, 2017; Ley, 2015). Moreover, due to technological advancements and potential shifts in energy regulations at both the national and international levels, the code is susceptible to modifications in the future (Ohunakin et al., 2018).

The Nigerian Building Energy Efficiency Code (BEEC) was developed in stages with the consideration of stakeholder's view (FMPWH, 2016; Nwofe, 2014).

1. Development of the National Building Energy Efficiency Guideline (BEEG) promoting bioclimatic buildings, considering stakeholders' view. This was approved and launched by the FMPWH in June 2016 (Akande et al., 2015).
2. Development of the Technical BEEC Study identifying minimum energy efficiency requirements and other essential elements of the BEEC (Akinwolemiwa and Gwilliam, 2017).
3. Development of the Draft National Building Energy Efficiency Code based on the BEEG and the Technical BEEC Study and validated by means of stakeholder review processes (Akinwolemiwa and Gwilliam, 2017).

The key objectives of NBEEC are:

1. Energy Efficiency: To improve the energy performance of buildings through setting minimum requirements and standards for energy efficiency in various aspects of building design, construction, and operation. Some of the energy efficiency interventions include lightning systems, insulation etc. (Oyedepo, 2012; Akinwolemiwa et al., 2018).
2. Compliance and Enforcement: To outline the mandatory requirements building stakeholders such as homeowners, developers, and architects must adhere to achieve compliance. As NBEEC makes provision for inspections, audits, and certification processes, this ensures compliance with the prescribed energy efficiency standards (BEEC, 2017; Nwofe, 2014).

3. Capacity Building and Awareness: To educate stakeholders in building and construction industry on energy-efficient building practices and benefits of NBEEC compliance through capacity building and awareness promotion. This includes training programs and workshops (BEEC, 2017; Nwofe, 2014).
4. Market Transformation: To transform the building and construction market through incentives that increase availability and affordability of energy efficient solution, therefore creating a market demand for sustainable buildings (Ohunakin et al., 2018; Emodi and Yusuf, 2015).
5. Environmental Impact: To contribute to Nigeria’s effort to address climate change through the mitigation of its building sector GHG emissions due to high energy consumption (Olaniyan et al., 2018; Oyedepo, 2014).

Building Energy Label – Prescriptive Based		
Rating (Star)	Intervention	Minimum Specification
1	Window to wall ratio or shading	20% maximum or shading as per BEEC Calculator.
2	<ul style="list-style-type: none"> a. Window to wall ratio or shading b. Lighting -Residential c. Lighting -Office 	<ul style="list-style-type: none"> a. 20% maximum or shading as per BEEC Calculator. b. Maximum lighting power density 6 W/m² c. Maximum lighting power 8 W/m²
3	<ul style="list-style-type: none"> a. Window to wall ratio or shading b. Lighting -Residential c. Lighting -Office d. Roof insulation 	<ul style="list-style-type: none"> a. 20% maximum or shading as per BEEC Calculator. b. Maximum lighting power density 6 W/m² c. Maximum lighting power 8 W/m² d. Minimum R-value 1.25m²K/W
4	<ul style="list-style-type: none"> a. Window to wall ratio or shading b. Lighting -Residential c. Lighting -Office d. Roof insulation e. Air conditioning minimum performance 	<ul style="list-style-type: none"> a. 20% maximum or shading as per BEEC Calculator. b. Maximum lighting power density 6 W/m² c. Maximum lighting power 8 W/m² d. Minimum R-value 1.25m²K/W e. Minimum EER/COP 2.8 and Inverter Compressor

Figure 2.24: Building Energy Label – Prescriptive Based

(Source: BEEC,2017)

Figure 2.24 shows the Prescriptive Path to compliance. A building is deemed to be in compliance with BEEC if all prescriptive requirements of the BEEC have been met from Roof insulation, window to wall ratio and shading, maximum lighting power density to air-conditioning type.

Building Energy Label – Performance Based	
Rating	Allowance for Exceeding BEEC Compliant Building
1 Star	40% to 30%
2 Star	30% to 20%
3 Star	20% to 10%
4 Star	10% to 0%
5 Star	0% and below

Figure 2.25: Building Energy Label – Performance Based

(Source: BEEC, 2017)

Figure 2.25 shows the performance path to compliance. A building is deemed to be in compliance with BEEC if its theoretical annual energy use is less than that of a reference building that complies with the requirements of the prescriptive path to compliance.

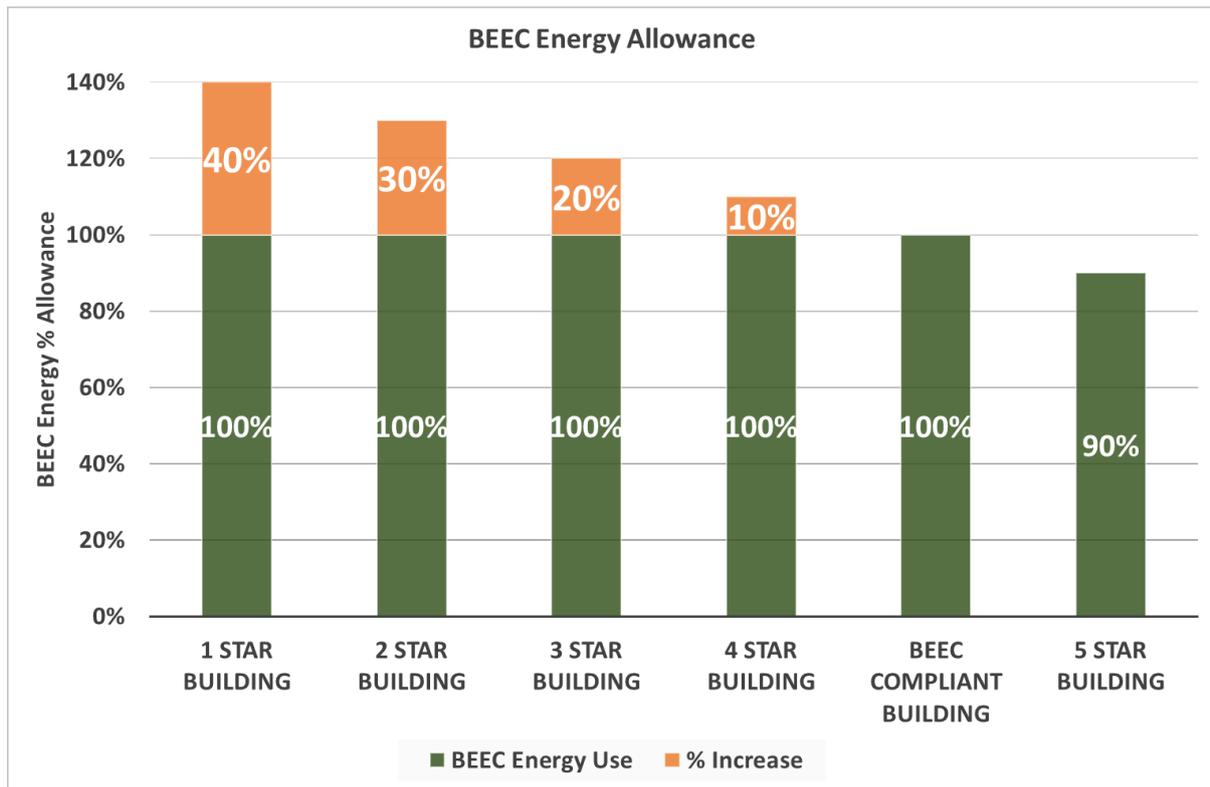


Figure 2.26: BEEC Energy Allowance

(Source: BEEC, 2017)

Figure 2.26 shows BEEC energy allowance.

In conclusion, NBEEC is crucial in advancing energy-efficient practices in Nigeria, therefore, the effective implementation of this code should involve a collaborated effort among various stakeholders in the industry, including government agencies, industry professionals, developers, and researchers.

2.12 Technological Solutions / Interventions for achieving NZEBs in Nigeria

The utilisation of technology is of utmost importance in the attainment of NZEBs (Schmitt, *et al.*, 2019). Technological advancements facilitate the achievement of energy efficiency, the seamless integration of renewable energy sources, and the implementation of efficient building management strategies (Aliyu, Modu and Tan, 2018; Culaba, *et al.*, 2020). The system provides novel approaches to optimise energy usage, decreasing carbon emissions, and improving occupant comfort. The range of technological solutions encompasses renewable energy systems, advanced control and smart grid technologies, building energy management systems, and building energy modelling and simulation, among others (Enteria, Awbi and Yoshino, 2015; Schmitt, *et al.*, 2019).

In the Nigerian setting, where there is a significant and quick increase in energy consumption, the

implementation of these technologies plays a vital role. Some of these technological interventions are discussed below:

Renewable Energy Technology: Renewable energy constitutes an essential component of NZEB (Schmitt, *et al.*, 2019). In the context of addressing the energy requirements of buildings, this approach presents a viable alternative to conventional energy sources derived from fossil fuels, as it delivers environmentally friendly and renewable sources of energy (Hyde *et al.*, 2012). Additionally, it provides several advantages, like achieving energy self-sufficiency and reducing costs. Renewable energy technologies encompass a variety of systems, such as solar photovoltaic systems, geothermal systems, biomass and bioenergy technology, wind turbines, and hydropower, among others (Good, Andresen and Hestnes, 2015).

Solar Photovoltaic System: It is one of the most widely adopted energy technologies for NZEBs (Culaba, *et al.*, 2020). It works by converting sunlight directly into electricity using photovoltaic panels. This electricity is clean, and can be generated onsite, therefore reducing reliance on the grid. Excess solar energy can be fed back to the grid using net metering (Culaba, *et al.*, 2020). With the abundance of solar energy in Nigeria, the potential for this technology is enormous.

Solar Water Heating System: This technology has the potential to be employed to fulfil the hot water requirements in residential buildings, thereby mitigating the necessity for conventional heating methods that are significantly dependent on energy (Culaba, *et al.*, 2020).

Wind Turbine: In regions characterised by advantageous wind conditions, this technique exhibits significant potential. On-site installation of small-scale wind turbines can be employed as a means of electricity generation (Good, Andresen and Hestnes, 2015)..

Geothermal Energy System: it utilises the heat stored beneath the earth's surface to generate electricity and heat or cool buildings (Good, Andresen and Hestnes, 2015). For example, geothermal heat pumps can provide space heating and cooling by transferring heat to and from the ground. When integrated with other renewable technology sources, the energy performance of buildings can be optimised.

Hydropower System: This system utilise energy from moving water to generate electricity (Ley, 2015; Good, Andresen and Hestnes, 2015). Although this would often involve large-scale hydroelectric plants, micro-hydropower systems can be utilised for NZEBs in areas with access to water bodies. Hydropower has played a significant role in Nigeria's electricity grid for several decades, constituting approximately 20% of the total grid supply at present (Ley, 2015). Although large-scale hydro power projects have been successfully implemented, there remains considerable untapped potential in the

realm of small hydropower throughout Nigeria (Ley, 2015). The country boasts numerous river systems, which collectively offer a capacity of 3.5GW through 70 micro dams, 126 mini dams, and 86 small sites. However, only a mere 1.7% (0.06GW) of this technically exploitable capacity is currently being utilised (Arup, 2017b; FMPWH, 2017).

Biomass Energy Technology: This technology is used to harness energy embodied in biomass to generate electricity, biofuels, or heat (Ochedi and Taki, 2022). Therefore, converting organic biomass materials into usable forms of energy. These biomass technologies offer sustainable and renewable alternative sources of energy to the conventional energy sources (Feng, *et al.*, 2019a).

Building Envelope Technology: This involves the design strategies, materials, and components adopted in the construction of a building's envelope (Passive House Institute, 2022). The building envelope plays a significant role in enhancing energy efficiency by serving as a protective barrier that separates the internal and exterior environments (Feng, *et al.*, 2019a; Ochedi and Taki, 2022; Ignatius, Wong and Jusuf, 2015; Hoque and Iqbal, 2015). Consequently, technological interventions in the building envelope are of utmost importance. The fundamental components of building envelope technologies include insulation, windows and glazing systems, air tightness or sealing, roofing systems, and thermal mass. The implementation of these technologies has the potential to drastically decrease energy consumption and greatly enhance indoor environmental quality, therefore leading to the attainment of a sustainable building (Passive House Institute, 2022).

Building Energy Management Systems (BEMS) / Building Energy Management Technology: BEMS is an integrated system or technology that provides a framework that monitors, controls, and optimise energy consumption in buildings and further reduce operational cost (Shaikh et al., 2014). This enables building owners and users make informed decisions for sustainable and efficient building operations. The key functions of BEMS include energy monitoring and metering, automated control systems, etc. (Marinakos et al., 2013).

Energy Monitoring and Metering: this device measure and collect data on energy consumption in real-time through the continuous monitoring of energy usage at various points in the building (Ahmad *et al.*, 2016).

Automated Control Systems: this enables the automated control and optimisation of energy-consuming systems. Based on occupancy schedules, this system can adjust lightning levels, HVAC systems etc., through a centralised control panel (Ahmad et al., 2016).

Building Information Modelling (BIM): BIM refers to a comprehensive digital representation of a building's physical attributes and functional properties, encompassing elements such as building

systems, spatial relationships, and other pertinent features (Eastman et al., 2011). The utilisation of this technology has the potential to enhance the processes involved in the planning, development, and maintenance of architectural structures. Moreover, this system plays a pivotal role in attaining NZEB by fostering collaboration, information dissemination, coordination, and feedback among stakeholders involved in a building project (Ahmed and Asif, 2020; Gyoh, 2019). It establishes an ecosystem that facilitates the integration of energy-efficient design strategies throughout the various stages of building development, including design, construction, and operation. Additionally, it aids building professionals in promptly identifying conflict. The software incorporates energy analysis tools that facilitate comprehensive energy simulations and performance assessments. These evaluations pertain to the building's energy consumption, demand, and potential for renewable energy utilisation. The analysis is conducted based on the BIM model and additional input data (Azhar et al., 2011). By leveraging this software, designers gain the ability to automate the generation of alternative design iterations, taking into account predefined parameters. Ultimately, BIM functions as a centralised store for many types of information, encompassing energy-related data such as equipment specifications, energy performance benchmarks, and maintenance schedules (Sadeghifam, *et al.*, 2019). Consequently, this facilitates the monitoring and assessment of performance.

In conclusion, by leveraging the capabilities of BIM technology, stakeholders can make effective decisions, enhance energy performance, and optimise building performance, and improve overall performance and functionality of their buildings to achieve NZEB.

2.13 Case Study

2.13.1 CASE STUDY 1 – Colombia: The path to Net-Zero.

Justification for Study: Colombia, like Nigeria, is recognised as one of the world's emerging economies (World Bank, 2017). The nation is actively leading the effort to decarbonise the built environment, making notable progress towards the ambitious objectives outlined in the Paris Agreement. Over a span of four years, the green building market in the Latin American country has experienced a remarkable rise in market penetration, progressing from 0% to 20%, mostly attributed to the implementation of the IFC's EDGE certification standard (IFC, 2019). Approximately 6.1 million square metres of green space have been EDGE certified, along with the construction of approximately 73,000 green homes (IFC, 2019). It is noteworthy that two-thirds of these homes are affordable housing (IFC, 2019). According to Iván Duque Márquez, President of Colombia, Colombia boasts the first green building code in Latin America. Furthermore, the country has emerged as a frontrunner in the region in terms of the number of projects and square metres of floor space certified by EDGE (IFC, 2019; United Nations, 2020). As of 2021, five commercial banks in Colombia are offering green financial

products in the construction sector (IFC, 2019). This development has positioned Colombia as a prominent financial hub for investment in green buildings within the Latin American region.

In conclusion, Colombia was among the few emerging economies whose strategic plan was highlighted in the UNEP's 2022 Global Status Report for Building and Construction. This rationale supports the selection of Colombia's roadmap as an appropriate case study.

Overview

Colombia, situated on the continent of South America, is home to around 52 million inhabitants as of 2022 (Roa *et al.*, 2022; DANE, 2023). It encompasses a land area of 1,141,748 square kilometres (km²) (World Bank, 2017). This positions the country as the second most populated nation in South America, following Brazil, and places it within the top 30 most populous countries globally (UN DESA, 2022). Approximately 81% of the population lives in urban areas (World Bank, 2017; IEA, 2023). The region experiences a tropical environment characterised by minimal variations in temperature throughout the year (Ruiz *et al.*, 2012). This country is classified as one of the twelve megadiverse nations worldwide and harbours about 10% of the documented species on the planet (OECD, 2014; CBD, 2022). Colombia encompasses four primary climatic zones, namely the lower-lying tropical zone, the temperate zone, the cold zone, and the paramos zone (IDEAM, 2020). Climate change poses a significant concern in Colombia, as the nation exhibits a high level of vulnerability to its impacts (DNP, 2018). Coastal communities, in particular, confront escalating risks of flooding, landslides, water scarcity, and erosion (UNGRD, 2021). However, the South American nation has implemented a comprehensive climate strategy, which has received widespread support and endorsement through its participation in the Paris Agreement (UNFCCC, 2015). This policy includes a commitment to reduce emissions by 20 percent by the year 2030 (GlobalABC, 2020; IFC, 2019; MADS, 2020). The country initially presented its Intended NDC to the UNFCCC in 2015 (Government of Colombia, 2015). The revised version of the UNFCCC was filed by the country in December 2020 (UNFCCC, 2020). In this submission, the country made a commitment to reduce its GHG emissions by 51 percent by the year 2030 and strive towards attaining carbon neutrality by 2050 (Goncalves, 2020). Following this, Colombia has implemented the requisite measures to accomplish this objective (DNP, 2021).

The path to Net-Zero

Colombia has emerged as a model for other Latin American nations, as it has successfully attained a market penetration of 0%–20% of green buildings within a mere span of four years (WorldGBC, 2023; GlobalABC, 2020; CCCS, 2022). But how was this achieved? The strategies employed to accomplish this remarkable feat warrant exploration, hence the reason for this study.

At the heart of this accomplishment is the effective integration of governmental incentives, both local

and international collaborations, technical support for developers, and innovative green financial options (WorldGBC, 2023; GlobalABC, 2020; IFC, 2021)

In 2015, the Colombian government officially approved a Green Building Code, which was subsequently accompanied by the introduction of a policy aimed at providing tax incentives (WorldGBC, 2023; MADS, 2015). These incentives were designed to facilitate the financial viability of adopting technical measures, such as energy-efficient air conditioning systems. The green building code would subsequently prove to be instrumental in driving Colombia's Net-Energy Ambition (WorldGBC, 2023; OECD, 2014; DNP, 2018). In the Latin American region, the green building code implemented in Colombia stands out as the pioneering regulation that has been enforced as a compulsory requirement for both new residential and commercial constructions (CAMACOL, 2020). The green building code has generated awareness, prompting the financial industry to respond by providing green bonds (Bancolombia, 2022). Loans were made available for green projects at interest rates lower than those prevailing in the conventional market. Furthermore, even more favourable rates were pledged for projects demonstrating a higher level of environmental sustainability (Superintendencia Financiera de Colombia, 2021). The reaction of the banking sector in Colombia had a ripple effect as it initiated a transformation in the market for green building and green finance across the Latin American region, thereby motivating all sectors of business to incorporate EDGE certification into their projects (IFC, 2020).

In 2017, IFC formed a partnership with the Colombian Chamber of Construction (CAMACOL) with the goal of promoting the adoption of EDGE certification as a strategic mechanism for facilitating the integration of sustainable practises within the Colombian construction industry (CAMACOL, 2018). The partnership led by CAMACOL served as a catalyst for the training of its members in the use of EDGE software. This collaboration resulted in remarkable achievements, as Colombia witnessed an unparalleled expansion in EDGE certification. The country achieved unprecedented records in terms of certified floor space and market penetration, surpassing any other region (EDGE Buildings, 2022).

In the year 2020, the IFC established a legally binding agreement with two esteemed Colombian universities, namely Pontificia Universidad Javeriana and Universidad de la Salle (Roa *et al.*, 2022; IFC, 2020). The purpose of this arrangement was to facilitate the provision of the course titled "Design for Greater Efficiencies," which had been collaboratively designed with the valuable contributions of ETH Zurich, a renowned public institution located in Zurich, Switzerland (ETH Zurich, 2021). The main goal of the Design for Greater Efficiencies course is to provide comprehensive training to aspiring architects and building professionals, with a specific focus on the principles and practises of designing and constructing structures in a highly efficient manner. The target is to provide training to a total of

45 professionals annually at each university (Pontificia Universidad Javeriana, 2021; Universidad de la Salle, 2021).

Despite the immense success achieved by Colombia in the construction sector in recent years in terms of the green revolution, it is important to note that sustainable building practises are yet to be adopted in all territories (IDEAM, 2020). For this reason, the Ministry of Housing, City, and Territory, the National Planning Department, the Colombia Green Building Council (CCCS), CAMACOL, and IFC are collaborating to create incentives that will drive the country towards total carbon neutrality (MinVivienda, 2022; DNP, 2021; CCCS, 2023).

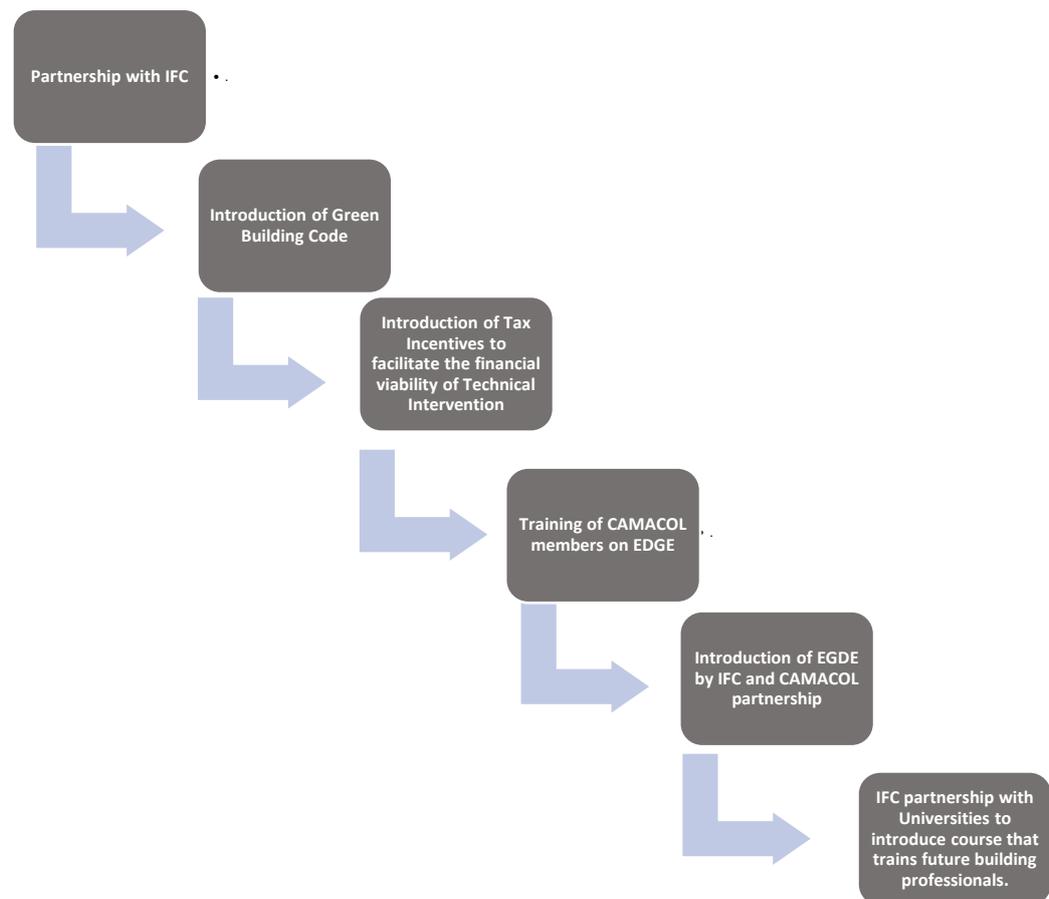


Figure 2.27: Colombia's path to Net-Zero

(MITSIDI PROYECTOS, 2022)

The roadmap to achieving Net Zero in Colombia's building sector is depicted in Figure 2.27. The strategies encompass strategic alliances, the introduction of a green building code, tax incentives, training, and more initiatives.

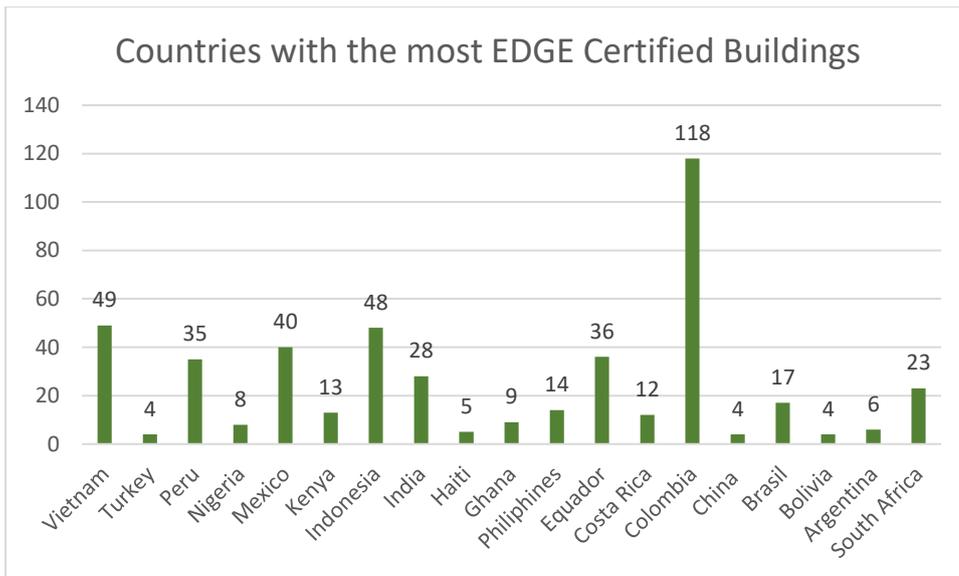


Figure 2.28: Countries with the most EDGE Certified Buildings

(Source: MITSIDI PROYECTOS, 2022)

Figure 2.28 presents a visual representation of the leading 19 countries globally, ranked by the number of buildings that have obtained EDGE certification. According to the graph, Colombia exhibits a notable advantage, as it encompasses 118 out of the total 473 buildings depicted in the graph. This demonstrates the influence of EDGE on the green construction sector in Colombia.

Summary of Findings and Lesson Learned

Colombia's notable case study involves rapid progress towards achieving net-zero emissions in its building sector. Over a span of four years, the green building sector in the country experienced significant growth, increasing from a negligible percentage to a notable 20%. This remarkable progress was driven by IFC's EDGE certification standard. In addition, Colombia has achieved this feat by addressing the following in its strategic roadmap: the development, implementation and enforcement of the green building code, the establishment of partnerships with banks and universities, the provision of tax incentives, and capacity-building initiatives, amongst others. This case study provides useful insights into the strategies that might be employed to achieve comparable objectives in emerging economies such as Nigeria.

2.13.2 CASE STUDY 2 – Costa Rica: The path to Net-Zero

Justification for study: Costa Rica has gained significant recognition for its notable accomplishments in the areas of sustainable development and renewable energy (World Bank, 2017). The nation of Central America has achieved significant advancements in the field of NZEBs, leading to its recognition as a prominent global model in the pursuit of decarbonisation (IFC, 2023).

Costa Rica, like Nigeria, is considered an emerging economy (World Bank, 2017), making it a suitable case study for a comparative analysis with Nigeria. Examining Costa Rica's progress towards achieving Net Zero will offer a valuable perspective on its path towards attaining carbon neutrality.

Overview

Costa Rica is a nation situated in Central America, characterised by a populace of over 5 million individuals and encompassing a land area of approximately 51,060 Km² (World Bank, 2017; CRS, 2022). The nation in Central America is geographically next to Nicaragua in the north, Panama in the south, the Caribbean Sea in the east, and the Pacific Ocean in the west (World Bank, 2017). Costa Rica exhibits a tropical environment where the average temperature hovers around 22 degrees Celsius (CRS, 2022; IMN, 2023). The region experiences two distinct climatic seasons, namely the dry season and the rainy season. The dry season spans from December to April, while the rainy season occurs from May to November (IMN, 2023).

Costa Rica, as a party to the 2015 Paris Agreement, has made a commitment to achieve complete decarbonization across all sectors of the economy by the year 2050 (World Bank, 2020; Goncalves, 2020; MINAE, 2019). Costa Rica has implemented a robust strategy to attain a carbon-neutral economy by the year 2050, aligning with the overarching goals outlined in the 2015 Paris Agreement (Goncalves, 2020; Government of Costa Rica, 2019). The proposed strategy encompasses a comprehensive strategic framework aimed at achieving decarbonisation of the economy, fostering job creation, and expediting sustainable growth (MIDEPLAN, 2022). The transformation of the country's present economic development model into one that is centred on bioeconomy, green growth, inclusivity, and the improvement of citizens' wellbeing has been recognised as relying on decarbonisation and resilience (MINAE, 2020). The nation has made significant advancements in its pursuit of decarbonisation objectives, particularly in the area of renewable energy (IEA, 2023). Presently, the main source of electricity generation within the nation stems from renewable sources, accounting for over 95% of the total (World Bank, 2020; IEA, 2023; ICE, 2022). However, it is projected that by the year 2030, the entirety of electricity production will be derived exclusively from renewable sources, thereby achieving a complete transition to renewable energy (Aliyu, Modu and Tan, 2018; MINAE, 2021). The nation has constantly made substantial investments in the development of renewable energy infrastructure, with particular emphasis on hydropower, solar, wind, and geothermal energy sources (ICE, 2022). The investment made by Costa Rica in renewable energy sources has not only resulted in a significant reduction in carbon emissions but has also facilitated the development of NZEBs (GBCCR, 2023).

Costa Rica's National Decarbonisation Plan (2018 – 2050)

The foundation of Costa Rica's achievements can be attributed to a robust policy and legal framework. The National Decarbonisation Plan sets forth ambitious targets for achieving a carbon-neutral economy by the year 2050 (World Bank, 2018; Kuzdas, *et al.*, 2015; WorldGBC, 2023). This comprehensive plan includes particular strategies aimed at enhancing energy efficiency and promoting the use of renewable energy sources. Costa Rica has implemented and actively advocated for a range of initiatives aimed at facilitating the development of NZEBs, which encompass the implementation of green building certification programmes (GBCCR, 2022). In addition, several measures, including feed-in tariffs, tax incentives, and regulatory frameworks, have been implemented to promote the uptake of renewable energy technologies in buildings (ICE, 2021; MINAE, 2020).

The Plan encompasses four key sectors of the economy, namely (I) Transport and Sustainable Mobility, (II) Energy, Green Building and Industry; (III) Integrated Waste Management, and (IV) Agriculture, Land Use Change, and Nature-Based Solutions (Government of Costa Rica, 2019). Each sector is accompanied by specific action plans. The following section will delve into the sector relevant to this study.

Action Plan for Energy, Green Building, and Industry

- I. To integrate the national electricity system in a manner that provides the necessary capacity, flexibility, intelligence, and resilience to efficiently provide and regulate renewable energy at a competitive cost (ICE, 2022).
- II. The construction of buildings with varying purposes (such as commercial, residential, and institutional) is being pursued with a focus on achieving high-efficiency standards and employing low-emission technologies (MIVAH, 2021).
- III. The industrial sector undergoes a transformation by adopting processes and technologies that utilise energy derived from renewable sources or other efficient and sustainable low- and zero-emission sources (CICR, 2023).

The strategy additionally outlines measures aimed at facilitating this transformative shift across several industries. The strategy aims to implement a comprehensive reform of the New Institutionality of the Bicentennial to enhance its modernization, digitalization, and flexibility, enabling it to effectively navigate the transformative challenges associated with the emerging decarbonised economy (MIDEPLAN, 2022), to implement Green Tax Reform through the decoupling of the Ministry of Finance's earnings from the sales of petrol, as well as the adoption of carbon pricing measures (Ministerio de Hacienda, 2022), to facilitate decarbonisation efforts to secure financing and attract

foreign direct investment by promoting the establishment of public-private partnerships (CINDE, 2023), to advance digitalization and the attainment of a knowledge-based economy (MICITT, 2022), to political viability and societal acceptance of decarbonisation through the implementation of labour initiatives aimed at achieving a fair and equitable transition (MTSS, 2021), to reinforce the ideals of inclusiveness, human rights, and gender equality in order to support the process of decarbonisation (INAMU, 2023), to integrate the National Climate Change Metrics System in order to ensure the availability of accessible and up-to-date data regarding the progress of the decarbonisation programme. This integration would also facilitate the use of predictive modelling to inform decision-making processes (IMN, 2022), and lastly, the implementation of educational and cultural programmes aimed at facilitating the transition towards Costa Rica's bicentennial leadership in the substitution of fossil fuels with renewable energy sources (MEP, 2023).

The plan's Energy proposal entails a shift towards a renewable energy system, with the additional objective of facilitating the advancement of the industrial sector (MINAE, 2021).

The implementation of this plan is coordinated by the Presidency of Costa Rica, with the assistance of the Ministry of Planning and Economic Policy, the Ministry of Environment and Energy, and the Ministry of Finance inside the country (Government of Costa Rica, 2019).

Costa Rica's comprehensive roadmap to NZEB

Decarbonisation Axis 5: Development of buildings with various purposes, such as commercial, residential, and institutional, while adhering to stringent energy efficiency standards and employing low-emission methods (Government of Costa Rica, 2019).

Transformational Vision: By the year 2025, there will be a notable rise of 10% in the use of wood, bamboo, and other indigenous materials in the construction of buildings. By the year 2030, all newly constructed buildings will be planned and constructed using low-emission and resilience systems and technologies, while adhering to bioclimatic conditions. By the year 2050, it is projected that half of the commercial, residential, and institutional buildings would adhere to emission norms, which involve either high electrification or the utilisation of renewable energy for cooking processes and water heating (Ministry of Environment and Energy, 2020).

Table 8: Costa Rica's comprehensive roadmap to NZEB

(Source: Government of Costa Rica, 2019)

Period	Action Plan
2019-2022	1. To strengthen the regulations, standards, and incentives for the effective implementation of sustainable construction practices in buildings and other infrastructures.

	<p>Objective: To create and improve standards for low-emission sustainable construction practises, to generate or promote certification regulations for the public and private sectors, to identify various incentive schemes, such as green credits, subsidy reviews, acknowledgments, certifications, and awards, that can be utilised to expedite the adoption of low-emission construction practises in both private and public projects, and to develop a communication strategy that effectively enables individuals to obtain information and enhance their comprehension regarding sustainable low-emissions construction.</p> <p>2. To improve operating practices of existing buildings and other infrastructure that significantly reduce their impact on GHG emissions.</p> <p>Objective: To encourage the use of energy-efficient solar and refrigeration equipment, as well as air-conditioning systems with low Global Warming Potential (GWP) or derived from natural sources, in pre-existing structures in alignment with the provisions outlined in the Kigali Amendment, to facilitate the adoption of recognition initiatives such as the National Carbon Neutral Programme and the Ecological Blue Flag Programme (PBAE) across various categories, to prioritise the utilisation of sustainable materials with low carbon footprints, such as cement and green concrete.</p>
2023- 2030	<p>To Enhance management's ability to implement standards—technical rules and labels—in urban planning, new and existing buildings, equipment, and devices. The Energy Transition Fund aims to provide access to efficient technology for all segments of the population, particularly vulnerable populations, through fiscal and consumer finance.</p> <p>Scale projects and programmes aligned with the Public Procurement System, educate public institution suppliers, and implement recognition programmes for organisations, companies, and public institutions. To encourage the design and implementation of an MRV system for sustainable building in private and public projects and the creation of a data-centralizing organisation and accelerate the adoption of standards in construction/buildings.</p>
2031- 2050	<ol style="list-style-type: none"> 1. The State Public Procurement System effectively communicates with the market and functions within the framework of zero emissions protocols. 2. To achieve widespread acceptance of sustainable standards by at least 2040, it is necessary to enhance the fiscal aspects of just transition and consumer financing. This will enable equitable access to efficient technology for all individuals.

Table 8 presents Costa Rica’s comprehensive roadmap to NZEB

Summary of Findings and Lesson Learned

Costa Rica's notable accomplishments in the fields of sustainable development and renewable energy, which are in line with its unwavering commitment to decarbonization, make it a highly suitable case study. The study benefits from the nation's comprehensive National Decarbonisation Plan, which focuses on key aspects such as energy efficiency, renewable sources, and green building certification. This plan offers useful insights that align with the aim of this study. The plan has a comprehensive strategy that spans several fields, including Energy and Green Building. It outlines methods aimed at promoting the use of sustainable materials, implementing low-emission processes, and providing incentives to encourage sustainable practises. Costa Rica's visionary approach towards achieving

NZEBs and its long-term plan until 2050 provide a valuable framework that Nigeria might draw upon in its own endeavour to embrace NZEBs.

2.14 Chapter Summary

This chapter undertook an examination of relevant literature pertaining to NZEBs in emerging economies, with a specific focus on Nigeria as a case study. The literature review presented a thorough examination of the concept of NZEBs and its multifaceted dimensions. These encompassed an analysis of global advancements in NZEBs, their implications for emerging economies, their alignment with the SDGs, the impact of the COVID-19 pandemic, the regulatory frameworks and policies promoting green building practises, the significance of energy efficiency in buildings, the specific context of Nigeria, various leading green building standards, technological interventions for achieving NZEBs in Nigeria, and a review of best practices from two emerging economies – Colombia, and Costa Rica.

In its entirety, this chapter offers a comprehensive comprehension of NZEB, encompassing both global and regional viewpoints, policy frameworks, green building standards, technological advancements, and lessons from Colombia, and Costa Rica. This serves as a fundamental basis for the subsequent chapters, where data pertaining to the research questions will be gathered and analysed.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Chapter Introduction

This chapter delves into the multifaceted nature of the research process, drawing upon the established research onion model proposed by Saunders, Lewis, and Thornhill. The present chapter has been carefully organised to shed light on the multiple layers of the methodological approach employed in this study. The chapter commences with an exploration of the selected research philosophy, followed by an examination of the research approach and strategy. Furthermore, the chapter extensively examined the underlying justification for selecting the methods employed in this study, provided a concise overview of the time horizon, and comprehensively tackled the facets pertaining to collecting and analysing data. Following this systematic approach, the study sets out a solid foundation for a comprehensive and enlightening research endeavour.

3.2 Research Paradigm

The research paradigm encompasses a comprehensive framework comprising perceptions, beliefs, and awareness of different theories and methods employed in the process of conducting research (Saunders et al., 2019). The research paradigm encompasses the identification of the research philosophy and research approach employed to address the research question(s) (Saunders, 2017). The research philosophy and research approach are the initial components of the research onion, constituting its first two layers (Saunders et al., 2019). Figure 3.1.

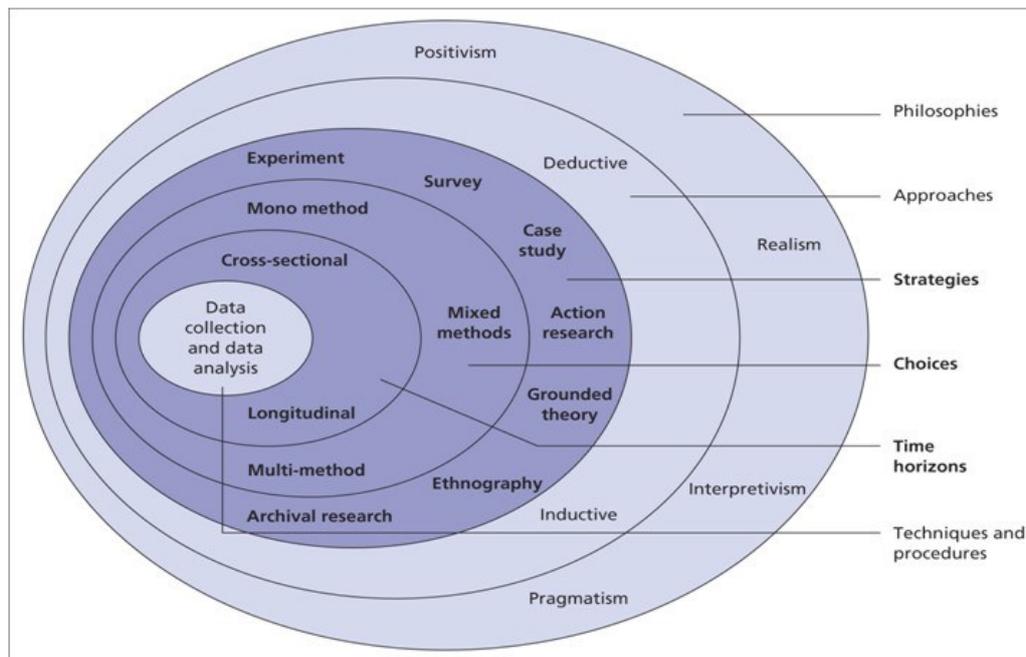


Figure 3.1: The Research Onion

(Source: Saunders et al., 2016)

Figure 3.1. depicts the research onion framework.

3.2.1 Research Philosophy

The concept of research philosophy pertains to a system of beliefs and assumptions that guide the process of knowledge development (Schwaferts, 2016; Booth et al., 2016). It encompasses a collection of concepts pertaining to the viewpoint adopted in doing research as well as the methodologies employed for data collection and analysis (Creswell and Creswell, 2018). Every scientific inquiry necessitates the implementation of a systematic approach and the adherence to a guiding philosophy (Kumar, 2019).

The study of research is typically approached from the perspectives of ontology, epistemology, and axiology (Lewis, 2013; Panneerselvam, 2018). This is commonly referred to as the philosophical stance or position (Kothari, 2004). In research, philosophical considerations are essential as they shape how researchers perceive and define the phenomena they are studying (Yin, 2017). A researcher's belief influence how they conceptualise the world, the assumptions they make about the nature of reality, and the way they analyse and interpret data (Sekaran and Bougie, 2016).

- Ontology, as a field of philosophical inquiry, pertains to the study of the fundamental nature of reality and the state of existence (Seely, 2016; Creswell and Creswell, 2018). It seeks to address questions pertaining to the ontological aspects of what exists (i.e., the fundamental nature and structure of reality), what can be known (i.e., the knowledge that can be derived from this reality), and the methods by which knowledge is obtained (Kumar, 2019). The field

of ontology investigates the fundamental essence of existence, the relationships among various entities, and the inherent characteristics of knowledge (Booth et al., 2016). Ontology encompasses two primary dimensions, namely objectivism and subjectivism (Kothari, 2004). According to Saunders, Lewis, and Thornhill (2016), Objectivism posits that social objects are independent realities that exist external to the individuals involved, whereas Subjectivism contends that social entities are constructed through the perceptions and acts of the social actors. Researchers may adopt different ontological perspectives, that may impact their research design and approach. This includes realism, idealism, constructivism, pragmatism, etc. (Yin, 2017).

- Epistemology deals with the examination of knowledge in its entirety, encompassing how it is acquired, justified, and disseminated (Kuang and Sumara, 2021; Panneerselvam, 2018). It pertains to questions about how we know what we know, the nature of knowledge, and the criteria for determining whether something can be considered knowledge or not (Lewis, 2013; Schwaferts, 2016; Sekaran and Bougie, 2016). This philosophical stance has a pivotal role in influencing the methods, approaches, and procedures employed for the generation and validation of knowledge (Kumar, 2019). Within the realm of epistemological philosophy, a relationship exists between the knower, who assumes the role of the researcher, and the known, which pertains to the subject of study (Creswell and Creswell, 2018). Researchers have the option to embrace several epistemological views, which can have implications for their research design and the way they interpret their findings (Kothari, 2004). Several prevalent viewpoints in the field include positivism, interpretivism, and pragmatism, among others (Yin, 2017).
- Axiology is a philosophical stance that examines the nature of values and their influence on the formulation of research design, methodology, and interpretation (Kivunja and Kuyini, 2017). It involves the examination of ethical considerations, individual biases, and the inherent value-based characteristics of choices. The concept of value has been debated as the fundamental driver behind all human behaviour (Panneerselvam, 2018). As such, axiology posits that a researcher's personal values significantly influence their approach to conducting research at each stage of the research process, as well as the significance they attribute to the findings (Kivunja and Kuyini, 2017; Farrow, Iniesto and Martin and Pitt, 2020; Creswell and Creswell, 2018). The values of researchers have the potential to shape various aspects of the research process, including the selection of research topics, the methods of data collection and analysis, and the interpretation and presentation of research findings (Sekaran and Bougie, 2016). Furthermore, researchers can improve the transparency, integrity, and ethical

foundation of their work by taking into account axiological considerations (Yin, 2017). Axiology in research encompasses several crucial elements, such as ethical considerations, the relationship between participants and researchers, the representation and interpretation of data, societal responsibility, and value neutrality vs. value relevance (Yin, 2017).

According to Saunders, Lewis and Thornhill (2016), it is important for researchers to possess the capacity to comprehend and express their convictions on the fundamental nature of reality, what can be known about it, and how this knowledge can be acquired. Therefore, the need for researchers to carefully select a philosophical framework that will serve as a guiding principle for their research endeavours. The selection of a philosophical framework is contingent upon the researcher's perspective on the relationship between knowledge and its development (Kumar, 2019). The selection of a philosophical framework is primarily contingent upon the specific research question that is to be addressed (Creswell, 2018). Hence, it may be argued that no research philosophy holds inherent superiority or inferiority over another, as asserted by Saunders, Lewis, and Thornhill (2016). Figure 3.1 shows four distinct research philosophies, namely Positivism, Realism, Interpretivism, and Pragmatism.

- **Positivism:** Positivism believes only factual knowledge gained through empirical evidence (i.e. objective observation and experiment), is reliable to understand and explain the world (Kumar, 2019). Therefore, research findings are observable and quantifiable. The approach is based on data collection and hypothesis development which will be tested and approved, and a theory developed for further research (Creswell, 2018). Positivism research is independent from the study with no provision for human interests within the study (Kivunja and Kuyini, 2017; Kumar, 2019). Some characteristics of positivism includes empirical observation, quantitative data analysis etc. (Kumar, 2019). As the study aims to develop a strategic roadmap, which involves understanding human perspectives, experiences, and contextual factors, rather than solely relying on empirical observations and quantifiable data, this philosophy was therefore deemed unsuitable for the study.
- **Realism:** Realism is a philosophical subfield within the realm of epistemology that pertains to the investigation of scientific inquiry (Yin, 2017). Realism posits that the veracity of reality and the presence of objects are inherently independent of the human intellect (Pandey and Pandey, 2015; Onwuegbuzie, Leech and Collins, 2015). The two main classifications within the realm of realism are direct realism, which pertains to the explanation of sensory experiences and the acquisition of knowledge by researchers, and critical realism, which posits that sensory experiences are representations of the external world rather than direct reflections of reality (Creswell, 2009; Yin, 2017). Realism is a philosophical perspective that asserts the

existence of objective phenomena in the world (Kumar, 2019). Researchers use this perspective to discover and comprehend these underlying realities through empirical study (Creswell, 2018). While realism acknowledges the existence of an objective reality, the study's focus is on developing a practical and actionable roadmap rather than discovering and comprehending underlying realities through empirical study (Booth et al., 2016). The study's aim is not to investigate scientific inquiry or the nature of reality but rather to provide a solution to a real-world problem by integrating multiple perspectives and data sources hence this philosophy was deemed unsuitable for the study.

- **Interpretivism:** Interpretivism, a philosophical discipline of epistemology, emerged in response to critiques of positivism (Braun and Clarke, 2013). Interpretivism places significant emphasis on the significance of comprehending and interpreting human experiences, behaviours, and social phenomena within their natural settings (Farrow, Iniesto and Martin and Pitt, 2020). As such, interpretivism incorporates the consideration of human interests into its scholarly inquiry. The underlying assumption posits that the nature of reality is intricate and socially constructed, leading individuals to attribute significance to their own experiences (Braun and Clarke, 2013). As a result, research within this particular framework aims to reveal these significations and offer a more profound understanding of the subjective dimensions of human existence (Creswell, 2018). While interpretivism emphasizes understanding human experiences and behaviours, the study's primary aim is to develop a tangible solution (practical roadmap) rather than solely interpreting subjective experiences (Booth et al., 2016). Furthermore, the study incorporates both quantitative data from survey questionnaires and qualitative data from interviews, whereas interpretivism primarily focuses on qualitative methods (Kumar, 2019). This makes this research philosophy unsuitable for this study.
- **Pragmatism:** Pragmatism research philosophy is an approach to problem-solving that prioritises practicality and emphasises the significance of notions that are action-oriented (Lewis, 2013; Saunders, 2017). It acknowledges the existence of numerous perspectives in interpreting the world and conducting research, emphasising that no single viewpoint can fully capture the entirety of reality, therefore implying the presence of multiple realities (Sekaran and Bougie, 2016; Creswell, 2018). Pragmatism emphasizes the practical implications and applications of research findings, with the aim of addressing real-world problems and making meaningful contributions to favourable outcomes (Kumar, 2019). This prompts researchers to consider their research's relevance, efficacy, and potential influence on people, communities, and society (Sekaran and Bougie, 2016). This research philosophy

aligns well with the study's aim of developing a practical and actionable roadmap by integrating multiple methods, data sources, and stakeholder perspectives, while considering the unique context of Nigeria as an emerging economy.

Choice of research Philosophy and Justification - Pragmatism

Every research investigation should have a systematic methodology for its execution and a guiding philosophical framework (Creswell, 2018). Researchers, in their pursuit of doing effective research, must carefully select a philosophical framework to guide their investigations (Kumar, 2019). Additionally, they should possess the ability to construct their research in a manner that maximises the benefits associated with the chosen research methods while simultaneously mitigating any potential limitations (Lewis, 2013).

This study adopted a 'pragmatism' philosophy. The choice of this research philosophy was informed by the research aim, research questions, and the intended use of a mixed-methods technique.

The notion of a mixed-methods approach is derived from the underlying assumption of pragmatism (Lewis, 2013; Creswell, 2014). Pragmatism is an advanced philosophy that allows the integration of many methodologies, paradigms, assumptions, and methods of data gathering and analysis (Creswell, 2014).

Pragmatism is characterised by a practical or realistic orientation towards problem-solving, prioritising practicality over theoretical considerations or abstract ideals (Shannon-Baker, 2017). From an epistemological standpoint, the underlying premise is that research can prioritise practical comprehension of tangible, real-life matters rather than engaging in metaphysical deliberations over the essence of truth and reality (Seely, 2010; Maarouf, 2019).

Pragmatism not only justifies employing a mixed-method approach but also facilitates the adoption of alternative methodological approaches, allowing researchers to choose between quantitative, qualitative, or mixed research methods based on their alignment with the study (Shannon-Baker, 2017; Farrow, Iniesto and Martin and Pitt, 2020).

Moreover, given the study aim of developing a strategic roadmap for achieving NZEBs in Nigeria's residential sector, a pragmatic approach will facilitate the identification of feasible solutions to overcome the barriers hindering the realisation of NZEBs in Nigeria. It will enable the development of a well-informed, context-specific, and practical roadmap that can be effectively implemented by various stakeholders within the building sector.

Crucially, pragmatism recognises the significance of context and the real-world experiences of research participants (Lewis, 2013). By grounding the proposed roadmap in the realities and

perspectives of stakeholders involved in Nigeria's building sector, the study ensures that the recommendations and strategies are practical, useful, and applicable. Ultimately, this pragmatic underpinning aligns with the study's contribution to sustainable development and climate action through the scalable adoption of NZEBs in Nigeria's residential sector by providing a context-specific and actionable solution.

In conclusion, the adoption of this philosophical framework would facilitate the advancement of the study by developing a strategic roadmap that is practical, problem-oriented, and relevant to the specific circumstances in Nigeria.

3.2.2 Research Approach

Research approach is a subset of research philosophy (Saunders et al., 2019). There are three types of reasoning in research – deductive, inductive, and abductive. It is imperative to understand these approaches to advance the research design (Maarouf, 2019).

Deductive Approach / Reasoning

Deductive reasoning entails starting with a broad principle, theory, or hypothesis and thereafter subjecting it to scrutiny by means of specific observations (Shannon-Baker, 2017). Saunders, Lewis and Thornhill (2016) states that the process involves the development of a hypothesis based on an existing theory, followed by the formulation of a method to test the hypothesis. Deductive reasoning is a process that involves progressing from a broad idea, body of knowledge, or general theory to specific instances in order to ascertain the validity of the theory in those particular cases (Maarouf, 2019).

In a study context focused on investigating the alignment between observed phenomena and the anticipated outcomes based upon prior research, this approach is most suitable (Wiles, *et al* , 2013). The deductive approach is commonly linked to quantitative research and is often seen as well-suited to the positivist approach (Saunders, Lewis and Thornhill, 2016). This approach allows for the formation of hypotheses and the statistical testing of projected outcomes to a level of probability that is widely accepted (Creswell, 2014). In Saunders, Lewis and Thornhill (2016), it is posited that qualitative research techniques can be employed in circumstances where the expectations derived from pre-existing research differ from those generated through hypothesis testing, therefore allowing for a deductive approach.

Inductive Approach / Reasoning

The inductive approach is focused on the generation of theory through the analysis of evidence, employing research questions to delimit the scope of the investigation (Creswell, 2014). The initial

step in this approach involves making observations, which serve as the foundation for deriving broad principles or theories (Lewis, 2013). Subsequently, the collected data is examined for patterns and trends, with the aim of arriving at general conclusions (Douven, 2017). In essence, the process can be likened to constructing a theory from the ground up by analysing specific instances and then generalising the findings.

While this approach is commonly employed in qualitative research, where the lack of a guiding theory can minimise researcher bias during data collection, it can also be effectively utilised within the positivist paradigm (Lewis, 2013; Schwaferts, 2016). In this case, the data is initially analysed, and patterns are subsequently employed to inform the generation of results (Douven, 2017).

Abductive Approach / Reasoning

Abductive reasoning, also known as the abductive approach or abductive logic, is a form of logical inference that moves from an incomplete set of observations or data to the likeliest possible explanation or theory (Douven, 2017). It involves a process of exploring potential explanations and hypotheses that could account for the observed phenomena (Aliseda, 2016).

The abductive approach was first introduced by the philosopher Charles Sanders Peirce, who described it as "the process of forming an explanatory hypothesis" (Peirce, 1934, p. 171). In the abductive approach, researchers begin with a set of observations or empirical data and then work backward to construct the most plausible explanation or theory that could account for those observations (Aliseda, 2016). This process involves considering various potential explanations, evaluating their plausibility, and selecting the most likely or best-fitting explanation based on the available evidence (Braun and Clarke, 2013).

The abductive approach is particularly useful in situations where there is incomplete information or when existing theories or models fail to fully explain the observed phenomena (Douven, 2017). It allows researchers to generate new insights, hypotheses, or theories that can then be further tested and refined through additional research (Aliseda, 2016).

In the context of mixed-methods research, the abductive approach can be valuable for integrating and interpreting findings from multiple data sources, such as quantitative surveys and qualitative interviews (Braun and Clarke, 2013). By employing abductive reasoning, researchers can move back and forth between inductive and deductive processes, using insights from one method to inform the analysis and interpretation of the other, ultimately arriving at a more comprehensive and nuanced understanding of the phenomena under investigation (Douven, 2017).

Choice of Research Approach and Justification

The selection of deductive, inductive, or abductive reasoning in research is contingent upon several factors, including the research question, the accessible data, and the aim of the study (Creswell, 2018). The research approach employed in this study is an abductive one. Abductive reasoning aligns with a mixed-method approach involving survey questionnaires and expert interviews (Kivunja and Kuyini, 2017). It is a form of logical inference that starts with an incomplete set of observations and proceeds to the likeliest possible explanation for those observations (Kivunja and Kuyini, 2017). It involves moving back and forth between induction and deduction to arrive at the most plausible conclusion or theory (Douven, 2017; Aliseda, 2016). In the context of a mixed-method study that employs survey questionnaires and expert interviews, abductive reasoning is appropriate for the following reasons: Survey questionnaires typically provide quantitative data, which can be analysed inductively to identify patterns and relationships (Saunders, Lewis and Thornhill, 2016). However, this data alone may not provide a complete understanding of the underlying reasons or explanations for the observed patterns. Expert interviews, on the other hand, offer qualitative insights and subjective perspectives that can help explain and contextualize the quantitative findings from the survey questionnaires (Kumar, 2019). Abductive reasoning allows the researcher to move back and forth between the quantitative and qualitative data, using insights from one method to inform the interpretation and understanding of the other (Lewis, 2013). By employing abductive reasoning, the researcher can explore the likeliest possible explanations for the observed patterns in the quantitative data, drawing on the contextual knowledge and experiences shared by experts during the interviews. Abductive reasoning enables the researcher to develop plausible theories or conclusions that integrate both the empirical evidence from the survey questionnaires and the contextual understanding gained from the expert interviews (Douven, 2017).

In the case of this study, which aims to develop a strategic roadmap for achieving NZEBs in Nigeria, abductive reasoning would allow the researcher to combine the quantitative data from the survey questionnaires (e.g., identifying barriers and drivers) with the qualitative insights from expert interviews (e.g., understanding the contextual factors and stakeholder perspectives). This integration would lead to a more comprehensive and nuanced understanding of the factors influencing the adoption of NZEBs in Nigeria, ultimately informing the development of a practical and context-specific roadmap.

Therefore, abductive reasoning aligns well with a mixed-method approach involving survey questionnaires and expert interviews, as it facilitates the integration of quantitative and qualitative

data to arrive at the most plausible explanations and conclusions for the observed phenomena (Aliseda, 2006).

3.2.3 Research Strategy

Research strategy can be defined as a plan that a researcher intends to follow in answering a research question (Saunders, Lewis and Thornhill, 2016). The choice of a research strategy depends on the research question and other variables such as data required for the research and the purpose of the study (Panneerselvam, 2018). Research strategies can include experiments, surveys, case study, observation, grounded theory, systematic literature review, ethnography etc. In this study, a survey questionnaire, and an expert interview were adopted as a research method (Creswell and Creswell, 2018).

Survey Questionnaire: The survey questionnaire is a research instrument that involves gathering information from participants through series of questions (Creswell and Creswell, 2018). It is one of the most widely used strategies due to its efficiency and is best used for collecting data on narrow and well-defined topics (Hanafizadeh and Shafia, 2021). A survey questionnaire could be open-ended questionnaire or closed-ended questionnaire or a mix of both. For this study, a closed-ended questionnaire was adopted (Yin, 2017).

This strategy is appropriate for this study to capture the level of built environment professionals understanding of NZEBs, and the barriers and drivers of NZEBs through responses to the questions in the survey.

Expert Interview: The aim of expert interview is to gain expert knowledge into a phenomenon (Shannon-Baker, 2017). In this study, expert interview was adopted to draw upon the knowledge of NZEB experts. An expert interview is one of the most frequently used methods in empirical social research.

3.3.4 Choice of Method

The selection of a research method is contingent upon various elements, including the research aim, objectives, and questions at hand (Yin, 2017; Creswell and Creswell, 2018). Hence, it is imperative to accurately identify these elements in order to select the appropriate study method. This research employed a mixed-methods approach that combined both quantitative and qualitative techniques. The integration of these two approaches was employed to complement each other, therefore providing a more robust viewpoint for addressing the research questions (Bryman, 2016; Maxwell, 2013). The incorporation of these two methods offered a more panoramic view of the research landscape, enabling a holistic examination of the research problem from various angles. Mixed

methods research also facilitates the identification of associations or discrepancies between qualitative and quantitative data that have been gathered (Creswell and Creswell, 2018).

Mixed Method Research Design

Mixed method research is a research methodology that involves the systematic integration or combination of quantitative and qualitative research in a single study (Bryman, 2016; Creswell, 2014). The combination of quantitative and qualitative approaches provides a better understanding of the research problems than either method alone (Creswell and Creswell, 2018). Mixed method approach has been regarded as a more powerful and effective method of investigation (Farrow, Iniesto and Martin and Pitt, 2020; Lewis, 2013; Schwaferts, 2016). It provides strengths that offset the weaknesses of both quantitative and qualitative research and encourages the use of multiple paradigms rather than the typical association of certain paradigms to a specific method (Schwaferts, 2016). Both numeric and non-numeric data are collected in the data collection process (Lewis, 2013). The use of this approach in this study is justified as it enables comprehensiveness, capturing the diverse perspectives and experiences of various stakeholders involved in the multifaceted issue of achieving NZEBs in Nigeria (Creswell and Plano Clark, 2011). It also facilitates the development of context-specific solutions tailored to the unique socio-economic, political, and environmental context of Nigeria (Bryman, 2006). The quantitative method, through survey questionnaires, provided empirical data and statistical insights into the barriers, drivers, and strategies related to achieving NZEBs in Nigeria's residential sector. It identified key barriers, determined the importance of various drivers, gathered data on potential strategies and interventions, and provided quantitative evidence to support the development of the proposed strategic roadmap. The qualitative method, through expert interviews, complemented the quantitative data by offering in-depth insights, contextual understanding, and practical experiences. It explored the underlying reasons and perspectives behind the quantitative findings, provided a deeper understanding of Nigeria's unique context, offer real-world examples and best practices from successful NZEB projects, and captured the diverse experiences and recommendations of experts and stakeholders (Creswell and Plano Clark, 2011; Bryman, 2006). By integrating these quantitative and qualitative methods, the mixed-methods approach enabled a comprehensive understanding of the factors influencing NZEB adoption in Nigeria, facilitating the development of a robust, well-informed, and actionable strategic roadmap grounded in empirical data, contextual insights, and practical experiences.

Types of Mixed Methods Research Approach

Various types of mixed method research design exist, however there are three (3) primary types - Convergent parallel mixed methods, Explanatory sequential mixed methods, and Exploratory sequential mixed methods (Creswell, 2014). For this research, explanatory sequential mixed method

was adopted. Table shows the various types of mixed methods research approach and the adopted approach for this study.

Table 9: Types of Mixed Methods Research Approach.

(Source: Creswell, 2014)

Convergent parallel mixed method	The simultaneous gathering of both quantitative and qualitative data is a fundamental aspect of this process. The data is analysed individually, and the findings are subsequently synthesised to yield a holistic outcome (Creswell, 2014).
Explanatory sequential mixed method	In this type of mixed method research design, quantitative research is first conducted before qualitative research. Consequently, subsequent to the collection and analysis of quantitative data, the qualitative data serves to enhance this analysis by providing additional elaboration and contextualization of the quantitative findings (Creswell, 2014; Lewis, 2013). In this study, the quantitative survey questionnaire was employed to identify the barriers, drivers, and potential strategies related to NZEBs. The subsequent qualitative expert interviews will then provide in-depth insights and contextual understanding to explain the underlying reasons and perspectives behind the quantitative findings.
Exploratory sequential mixed method	It follows a sequence similar to the explanatory sequential method however this is done in reverse meaning qualitative research is carried out and findings from this study is used to develop the quantitative instrument (Wiles, <i>et al.</i> , 2013; Lewis, 2013).

Table 10: Qualitative, Quantitative, and Mixed Methods Approaches

(Source: Creswell and Creswell, 2018, p.18)

	Qualitative Approach	Quantitative Approach	Mixed Method Approach
Philosophical Assumptions	Constructivist / transformative knowledge claims	Postpositivist	Pragmatic
Strategies of inquiry	Phenomenology, grounded theory, ethnography, case study, and narrative	Surveys and experiments	Sequential, convergent, and transformative
Methods	Open-ended questions, emerging approaches, text, or image data	Closed-ended questions, predetermined approaches, numeric data (may include some open-ended questions)	Both open and closed-ended questions, both emerging and predetermined approaches, and both quantitative and qualitative data and analysis
Practices of research	<ul style="list-style-type: none"> Collects participant meanings. Focuses on a single 	<ul style="list-style-type: none"> Tests or verifies theories or explanations. Identifies variables to 	<ul style="list-style-type: none"> Collects both quantitative and qualitative data.

	<ul style="list-style-type: none"> concept or phenomenon. Brings personal values into study. Studies the context or setting of participants. Validates the accuracy of findings. Makes interpretations of the data. Employs text analysis procedures. 	<ul style="list-style-type: none"> study. Uses standards of validity and reliability. Observes and measures information numerically. Uses unbiased approaches. Employs statistical procedures. 	<ul style="list-style-type: none"> Develops a rationale for combination. Integrates the data at different stages of inquiry. Employs the practices of both qualitative and quantitative research
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Table 10 presents a framework developed by Creswell and Creswell (2018, p. 18) that classifies the qualitative, quantitative, and mixed-method approaches, along with a clearly delineated research methodological process for each approach.

Qualitative and Quantitative Method

Onwuegbuzie et al. (2015) suggests that there is a tendency for quantitative and qualitative researchers to perceive themselves as being in opposition, resulting in a polarisation of their methods of study and a tendency to solely adhere to either quantitative or qualitative approaches.

In the late 20th century, scholars held the belief that the coexistence of quantitative and qualitative paradigms was not feasible (Johnson, Onwuegbuzie and Turner , 2007;Onwuegbuzie, Leech and Collins , 2015). However, Creswell and Plano Clark (2007) countered this notion by asserting that both qualitative and quantitative research approaches encompass similar elements in their investigations. They argued that no single study can be purely classified as either quantitative or qualitative, as both methods share many common elements.

Historically, quantitative research has been the predominant method employed in research due to its perceived objectivity (Creswell, 2018). The emergence of qualitative research as a method of study occurred during the early 20th century, marking the second phase in the development of research methods (Creswell, 2018). Supporters of qualitative research contend that social reality is produced and, therefore, subjective (Bryman, 2016).

The distinction between the two research methodologies is predicated on their respective perspectives on the ontological nature of reality. The quantitative method is characterised by objectivity and a confirmatory approach, as it seeks to measure or quantify a single reality (Johnson, Onwuegbuzie and Turner, 2007). On the other hand, the qualitative method is subjective and exploratory, acknowledging the existence of multiple constructed realities that hold diverse meanings and interpretations, contingent upon the researcher's perspective or perception (Onwuegbuzie, Leech and Collins, 2015). Quantitative research is characterised by its deductive approach, wherein

ideas are tested by seeking evidence that either supports or refutes the hypothesis (Bryman, 2016; Hanafizadeh and Shafia, 2021). On the other hand, qualitative research involves the collection of data from individuals in order to discover themes, which in turn facilitate the development of theories through an inductive process (Creswell, 2009).

Quantitative method

The quantitative approach is a component of the positivist research philosophy, characterised by the researcher's detachment from the research context (Saunders, 2017; Schwaferts, 2016). The process entails the collection of quantitative data and subsequent statistical analysis, with the objective of identifying patterns and relationships (Bryman, 2016). A comprehension of the relationships among variables through the use of either descriptive or inferential statistical analysis is imperative for the gathering and examination of data employing quantitative methodology (Saunders, 2017). In this study, the quantitative approach was employed through the use of survey questionnaires to gather data on the barriers, drivers, and potential strategies related to achieving NZEBs in Nigeria's residential sector.

The quantitative approach offers several advantages in the context of this study. First, it provides objectivity as the data is numerical and measurable, reducing the potential for bias and subjectivity in the analysis (Creswell and Creswell, 2018). Second, with a large sample size, the findings from the survey questionnaires can be generalized to the broader population of construction professionals in Nigeria (Saunders, 2017). Third, the quantitative method allows for rigorous statistical analysis, revealing patterns and relationships among the variables under investigation, such as the relative importance of different barriers or drivers (Saunders, 2017). Fourth, data collection and analysis can be streamlined, making it possible to study a wide range of variables related to NZEBs efficiently (Kumar, 2019). Finally, the results obtained through the quantitative method can be replicated and verified by other researchers, enhancing the credibility of the findings (Creswell and Creswell, 2018).

However, it is essential to acknowledge the limitations of the quantitative approach. The quantitative data from the survey questionnaires may not reveal the underlying reasons or motivations behind the observed patterns, such as the specific contextual factors influencing the barriers or drivers to NZEB adoption in Nigeria (Saunders, 2017). Additionally, the quantitative method can be restrictive and may not be well-suited for exploring complex or sensitive topics related to NZEBs in depth (Kumar, 2019).

To address these limitations, this study employed a mixed-method approach, complementing the quantitative survey questionnaires with qualitative expert interviews. The qualitative component allows for a deeper understanding of the underlying reasons and motivations, as well as the

exploration of the unique socio-economic, political, and environmental context of Nigeria, which is crucial for developing a context-specific and actionable strategic roadmap for achieving NZEBs in the residential sector (Yin, 2017).

Qualitative method

The qualitative approach was employed through an expert interview to complement the quantitative survey questionnaire. It is a component of the interpretivism philosophy, wherein the researcher's connection with the subject plays a crucial role in comprehending the observable phenomenon (Onwuegbuzie et al., 2015; Maxwell, 2013). The primary objective of this approach is to gain insight into the fundamental meanings, emotions, and motives that underlie human behaviour by employing techniques such as interviews and observations (Onwuegbuzie, Leech and Collins, 2015; Maxwell, 2013). The qualitative methodology is predicated on the perspective or lived experiences of the participant during the data gathering process. It is characterised by its rigorous approach to inquiry, as it necessitates a substantial investment of time in conducting fieldwork in order to obtain answers to research questions (Yin, 2017).

The qualitative method offers several advantages in the context of this study. First, it allows for an in-depth understanding of the complex phenomena and subjects related to achieving NZEBs in Nigeria, providing rich and detailed insights (Creswell and Creswell, 2018). Second, the qualitative approach offers flexibility, as the direction and framework of the research can be revised based on emerging information and findings (Saunders, 2017). This flexibility enables the researcher to ask follow-up questions and explore unexpected avenues during the expert interviews, facilitating a clearer understanding of the targeted subject matter (Saunders, 2017). Third, the findings from the qualitative component can guide the development of theories or inform the design of future quantitative studies related to NZEBs in Nigeria (Kumar, 2019).

Furthermore, the qualitative approach provides a clear vision for the researcher, allowing them to understand the broader context and how the collected data fits into the bigger picture (Onwuegbuzie et al., 2015). Additionally, it can uncover emotions, motivations, and underlying reasons behind the behaviours and perceptions of stakeholders, which is crucial for understanding the barriers and drivers to NZEB adoption in Nigeria (Maxwell, 2013).

However, it is important to acknowledge the limitations of the qualitative approach. Subjectivity and the potential for bias are inherent in qualitative research, as the quality of the research heavily depends on the skills of the researcher and can be influenced by personal idiosyncrasies and biases

(Creswell and Creswell, 2018). Additionally, the qualitative findings may have limited generalisability due to small sample sizes and the contextual focus of the study (Saunders, 2017).

To address these limitations, this study employed a mixed-method approach, combining the qualitative expert interviews with quantitative survey questionnaires. The quantitative component provided objectivity, generalisability, and statistical analysis, complementing the in-depth insights and contextual understanding gained from the qualitative methods.

Comparison Between Qualitative and Quantitative Research Method

Table 11: Comparison Between Qualitative and Quantitative Research Method. Source: Creswell & Creswell (2018, p. 18).

	Qualitative Research Method	Quantitative Research Method
Research Philosophy	Interpretivism	Positivism
Research Approach	Inductive	Deductive
Data Classification	Subjective	Objective
Purpose	To gain insights into problems	To quantify data and generalise result
Data Collection	Non - statistical	Statistical usually in the form of tabulations.
Data Analysis	Identification of major themes	Descriptive and inferential statistics
Outcome	Explorative and/or investigative. Findings are inconclusive and cannot be generalised	Findings are conclusive and used to recommend a final course of action.

Table 11 presents a methodological comparison between the qualitative and quantitative research method.

3.2.5 Time Horizon

The time horizon explains how many points in time data is collected. Data can be collected cross-sectionally or longitudinally (Saunders, Lewis and Thornhill, 2016). Cross-sectional data involves the collection of data at a given point (Creswell, 2018). In contrast, longitudinal data involves the collection of data over a given period of time (Yin, 2017). For this study, a cross-sectional data was adopted as the study is a short-term study. One of the advantages of a cross-sectional study is that it permits the comparison of different variables at the same time (Saunders, 2017). It is also time and cost effective (Yin, 2017).

3.2.6 Data Collection and Analysis

This section will provide a discussion on the method that was employed for data collection, specifically focusing on the development and administration of the survey instrument. The method of

data analysis will also be addressed. Data collection and analysis are the final layers of the research onion (Saunders, 2017). The composition encompasses the techniques and procedures employed in the investigation. This study adopts primary data for its data collection.

Data Collection

Primary Data

Primary data refers to firsthand information that is obtained directly by the researcher. According to (Saunders, 2017), primary data can be obtained through several means, such as surveys, observations, and experiments. One of the key benefits of primary data collection is the researcher's complete control over the process since they are able to design it in a manner that aligns with the research aim (Dou and Toth, 2021). Additionally, collecting, and analysing data in person offers greater ease, accuracy, and reliability (Yin, 2017). Moreover, primary data collection ensures that the data obtained is current and up-to-date (Kumar, 2019). One significant drawback associated with primary data collection is its tendency to incur substantial costs and use significant amounts of time (Dou and Toth, 2021).

This study utilised a combination of survey questionnaire, and expert interviews as data collection methods. The selection of this method is predicated upon the specific data needs of the research endeavour and the aim of the study.

Sampling

There are two approaches that a survey can employ: a sampling method, which is a non-parametric method, and a census method, which is a parametric method (Pandey and Pandey, 2015; Sara, 2009). The sampling method pertains to the process of selecting a limited number of individuals as a representative sample of the entire population (Pandey and Pandey, 2015; Bryman, 2016). This method is commonly employed in academic research due to its ability to facilitate comprehensive and in-depth investigations while significantly reducing the time and financial resources required (Creswell and Poth, 2018). The census method encompasses the entirety of the population (Creswell, 2018). Data is gathered from the entirety of the population. Although this approach yields more precise and comprehensive data by eliminating any omitted subjects, it necessitates a significant investment of time and resources (Booth et al., 2016).

For this study, the Sampling method was adopted based on its demonstrated effectiveness in similar studies.

Methods of sampling

Table 12: Sampling Method

(Source: Creswell and Poth, 2018)

<p>Probability Sampling (Stratified Sampling)</p>	<p>A probability sample method involves the selection of a sample from a complete sampling frame of all eligible subjects. This gives all eligible subjects an equal chance of selection for the sample, therefore a generalization can be made from results of the study (Etikan and Bala, 2017). There are various types of probability sampling strategies, e.g., simple random sampling, systematic sampling, stratified sampling, and clustered sampling. However, a stratified sampling technique was chosen for the quantitative survey (survey questionnaire) to ensure representation from all subgroups of construction professionals in Nigeria.</p>
<p>Non-probability Sampling (Purposive Sampling)</p>	<p>Subjects are selected from a population using a subjective method. Types of non-probability sample size are convenience sampling, quota sampling, purposive sampling, and snowball sampling (Etikan and Bala, 2017). For this study, a purposive sampling strategy was deployed for the qualitative survey (expert interview). This method of sampling will enable the researcher to identify the Green Building Experts in Nigeria (Palinkas et al., 2015).</p>

Table 12 presents the sampling method deployed by this study to collect quantitative and qualitative data.

Sampling Strategy

In this section, the sampling strategy adopted for the survey (survey questionnaire and expert interview) will be discussed.

Survey Questionnaire

The individuals involved in the procurement process of buildings in Nigeria encompass a group of building professionals (Ochedi, 2018). Hence, the population under investigation in this study will consist of the Professional Standard Regulatory Bodies (PSRB) in Nigeria, namely the Nigerian Institutes of Architects (NIA), Nigerian Institute of Builders (NIOB), Nigerian Institute of Quantity Surveyors (NIQS), Nigerian Institute of Surveyors (NIS), Nigerian Institute of Town Planners (NITP), Nigerian Institute of Estate Surveyors and Valuers (NIESV), and Nigerian Society of Engineers (NSE). Furthermore, it should be noted that the Green Building Council of Nigeria (GBCN), an esteemed member of the World Green Building Council (WGBC), comprises various building professional organisations and will be included in the population. Given the aforementioned context, the chosen sampling technique will be stratified random sampling. This is to ensure that all building professionals are represented in the study sample. The cumulative population size of these entities will amount to approximately 100,000 individuals. Table 17. Using a sample size calculator, the recommended

sample size from a population of approximately 100,000 using a 10% margin of error, a confidence level of 90%, and a response distribution of 50% is determined to be 68. Hence, a minimum target of 68 respondents was required for the survey questions. Figure 3.3.

A survey questionnaire with a duration of 5 minutes was administered to the chosen professional bodies using the Google Forms platform, from which the data was collected.

Table 13: Population distribution across professional standard regulatory bodies in Nigeria.

Professional Standard Regulatory Bodies (PSRB) in Nigeria	Population
Nigerian Institutes of Architects (NIA)	12, 000
Nigerian Institute of Builders (NIOB)	20,000
Nigerian Institute of Quantity Surveyors (NIQS)	10, 000
Nigerian Institute of Surveyors (NIS)	2, 000
Nigerian Institute of Town Planners (NITP)	5, 000
Nigerian Institute of Estate Surveyors and Valuers (NIESV)	2, 280
Nigerian Society of Engineers (NSE)	50, 000
Green Building Council of Nigeria (GBCN)	211

Sample size calculator

What margin of error can you accept? %
5% is a common choice

What confidence level do you need? %
Typical choices are 90%, 95%, or 99%

What is the population size?
If you don't know, use 20000

What is the response distribution? %
Leave this as 50%

Your recommended sample size is **68**

Online surveys with Vovici have completion rates of 66%!

Alternate scenarios

With a sample size of	<input type="text" value="100"/>	<input type="text" value="200"/>	<input type="text" value="300"/>	With a confidence level of	<input type="text" value="90"/>	<input type="text" value="95"/>	<input type="text" value="99"/>
Your margin of error would be	8.22%	5.81%	4.74%	Your sample size would need to be	68	96	166

Figure 3.2: Raosoft Sample Size Calculator

Expert Interview

The careful and deliberate process of selecting experts plays a crucial role in ensuring the credibility and relevance of expert interviews (Sekaran and Bougie, 2016). The selection of green building

experts for participation in the expert interview was based on several criteria. Firstly, individuals possessing extensive knowledge and a demonstrated history of success in the field of NZEBs were intentionally chosen. Moreover, these individuals have a profound comprehension of sustainable building design, energy efficiency, and renewable energy systems, specifically within the realm of new-build residential buildings. Hence, their knowledge is strongly aligned with the research questions (Saunders, 2017).

Secondly, the selection of these experts was based on their practical experience and demonstrated engagement in projects and efforts pertaining to NZEBs in emerging economies. These individuals who have effectively implemented sustainable practices, technologies, or policies in building projects will offer significant practical perspectives (Creswell and Creswell, 2018). Thirdly, the experts chosen for this study have made notable contributions to the field through their research, publications, and leadership positions, thus establishing a robust reputation for their work in the areas of sustainable building practices and energy efficiency.

Furthermore, the representation of specialists from various geo-political zones in Nigeria was characterised by a significant diversity of perspectives. This will ensure a deeper understanding of the unique challenges faced by the various regions of Nigeria (Onwuegbuzie et al., 2015). In consideration of the study's aim, the experts were chosen based on their knowledge and experience pertaining to the Nigerian context. The professionals demonstrate a comprehensive understanding of the local building practices, regulatory frameworks, cultural factors, and unique challenges pertaining to Nigeria (Maxwell, 2013).

Through a meticulous assessment of these criteria, this study will involve professionals who possess the ability to make substantial contributions to the research and improve the overall quality of the findings.

Administration of Expert Interview

The expert interview was conducted through carefully designed telephone conversations, facilitated by the dissemination of a comprehensive interview outline questionnaire to each participant prior to the interviews. This preparatory step allowed the experts to reflect on the subject matter, formulate well-informed perspectives, and engage in substantive and focused dialogues, contributing to the depth and quality of the qualitative data collected. The telephone format provided flexibility, enabled participation from diverse geographical locations, and created a comfortable setting for open and candid discussions. By combining a structured approach with the ability to capture diverse perspectives and authentic insights, the administration of the expert interviews through this

methodology ensured a robust and enriching qualitative data collection process, fostering a comprehensive understanding of the subject matter from the esteemed panel of experts.

Data Analysis

Quantitative Data: In this study, the quantitative dataset was analysed using descriptive statistics and inferential statistics. Descriptive statistics is an essential aspect of data analysis, encompassing the process of summarising and describing the key characteristics of a given dataset (Creswell, 2018). It offers a concise representation of the central tendencies, variability, and distribution of the data (Lewis, 2013). While inferential statistics refers to a method of data analysis that makes inferences about populations based on sampling (Creswell and Creswell, 2018). This methodology is expected to yield significant findings regarding the respondents' perspectives on the main barriers and drivers that influence the implementation of NZEBs in Nigeria.

Qualitative Data: The analysis of qualitative data obtained from expert interviews necessitates a methodical approach to extract significant insights (Kumar, 2019). In this study, a thematic approach was employed. This approach will facilitate the understanding of the challenges, opportunities, and recommendations pertaining to the adoption of NZEBs in Nigeria (Creswell and Creswell, 2018). The following procedure was employed to analyse the dataset:

1. **Transcription:** The audio recording of the responses underwent manual transcription.
2. **Data Familiarisation:** The transcription was carefully examined to develop an understanding of the information conveyed by the experts.
3. **Coding:** The process of coding was employed to organise the data by assigning codes to distinct sub-themes found within the predetermined theme's transcription. This method facilitates the identification and analysis of fundamental concepts, ideas, or patterns inherent in the dataset. The research methodology involved the utilisation of both deductive coding, which is guided by the research questions, and inductive coding, which involves the identification of emerging themes.
4. **Theme Development:** The process of theme development involves the grouping of similar codes into broader thematic categories. The themes served as the main topics or recurring patterns that arise from the collected data.
5. **Data Exploration:** The process of data exploration was utilised to examine the relationships between various themes, aiming to determine the interconnections among distinct concepts and their contributions to the comprehension of achieving NZEBs in Nigeria.

6. Pattern Recognition: It involved the identification of recurring patterns, trends, or variations within the given dataset. In addition, consensus among the experts' viewpoints and dissenting opinions will be identified.
7. Interpretation: The meanings and implications of the identified themes were interpreted. Findings were related to the research questions and existing literature.
8. Validation: The interpretations were cross-checked with the original data to ensure they accurately represent the experts' perspectives.
9. Integration and Report: The processed data from the expert interview was integrated with the findings from the literature review, survey questionnaire, and case study. The results of the analysis were presented in a coherent and structured manner.

3.3 Ethical Consideration

The significance of ethical considerations in research cannot be overstated. The inclusion of ethical considerations guarantees that the study is carried out in a manner that is both ethical and responsible, demonstrating respect for the rights of the participants and maintaining the integrity of the research process (Barrow, 2022). This section exemplifies the cognisance of the ethical concerns associated with this study and delineates the measures implemented to assure the ethical conduct of the research, hence enhancing the overall transparency and integrity of the study.

- Informed Consent of Participants: First, the consent of the participants was sort by providing participants with the option to participate voluntarily and withdraw at any point without giving any reason of their withdrawal.
- Privacy and Confidential Information: the privacy and confidentiality of the participants was secured as the collected data could not be linked to any of the participants. The identities of the participants remained anonymous by assigning a pseudonymity to each of them to maintain their confidentiality.
- Data Storage: Collected data was stored safely in the University's storage system while observing the University's data protection policy.
- Ethical Review and Compliance: The research sought approval from the University's Research Ethics Committee through the University's Ethical Approval Form (appendix 1).
- Transparency: The research aim, and methodology was clearly communicated to the participants. Furthermore, the overall findings from this study have been reported transparently to help others evaluate its validity.
- Acknowledging Sources: Sources consulted for this study has been duly referenced.

3.4 Chapter Summary

In this chapter, the research technique was elucidated through the utilisation of the research onion framework, as developed by Saunders et al. The study systematically peeled through the various layers of the research onion to reveal the methodological approach utilised in investigating the barriers and drivers associated with achieving NZEBs in Nigeria. The initial step involved a discussion on the research philosophy to determine the philosophical approach adopted by the study. This was followed by a discourse on the research approach employed, the research choice, and the strategy employed for sampling. This chapter additionally elucidated the specific instruments and processes employed for collecting and analysing data. Ultimately, the study duly acknowledged and addressed the ethical considerations. The subsequent chapter will provide an analysis of the data that has been collected.

CHAPTER 4: RESULTS AND FINDINGS

4.1. Chapter Introduction

This chapter presents the results and findings from the survey questionnaire, and expert interview using the research methods described in the previous chapter.

4.2. Survey Questionnaire

The results obtained from the collected data have been presented in accordance with the structure of the survey questionnaire, which consists of four main categories, including sub-categories of closed-ended questions. Additionally, the survey concludes with an open-ended question soliciting recommendations. At the conclusion of the survey, a total of 70 responses were collected, surpassing the sample size of 68 by two additional responses.

1. This section is related to background information about you and your organization/company.

1.1 Which of the following categories best describes your profession?

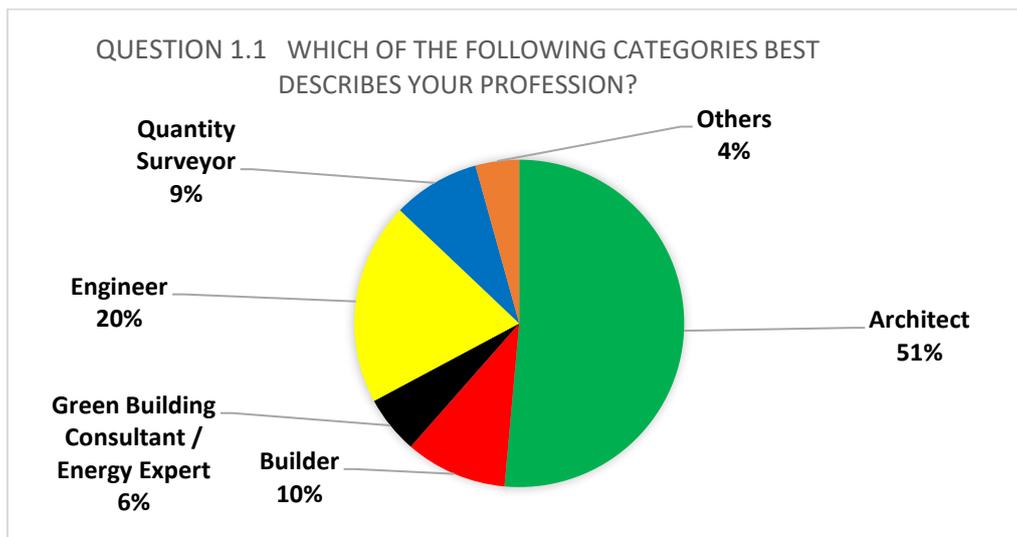


Figure 4.1: Profession of the respondents

The demographic data of the respondents, grouped according to their professions, is presented in Figure 4.1. Based on the data that was obtained, it is evident that Architects constitute a minimum of 51% of the respondents. Given the significant role that architects play in the process of building procurement, their involvement is highly relevant and contributes to the advancement of this research. Engineers ranked second with a significant margin, accounting for 20% of the total. Builders make up the top three (3) with a percentage of 10%. Quantity surveyors, Green building consultants / Energy experts accounted for 9% and 6% of the respondents, respectively, placing them in the fourth and fifth positions. The remaining 4% of respondents belonged to professions in the sector that were not specifically listed.

1.2 Which of the following best describes the sector you work in?

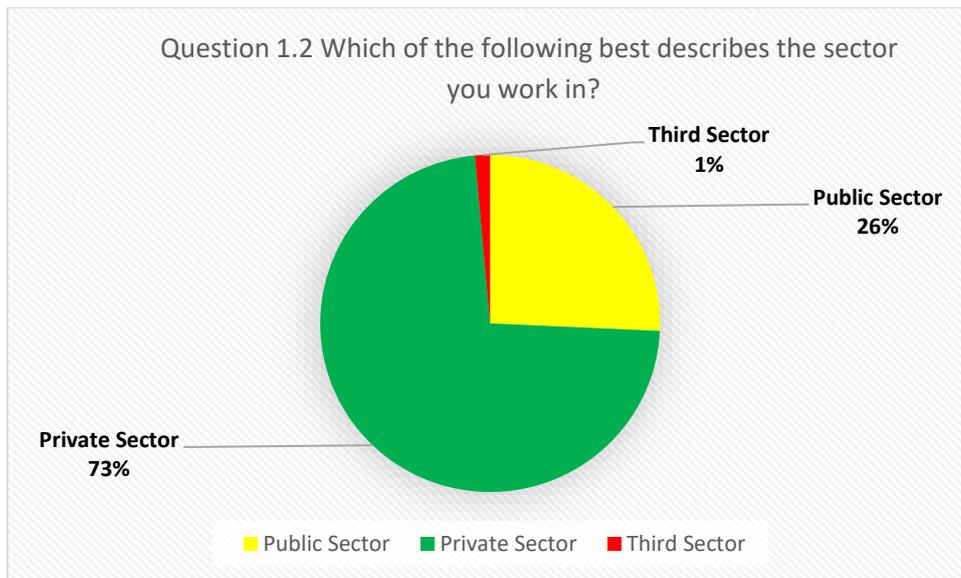


Figure 4.2: Sector of the respondents

The diagram depicted in Figure 4.2 illustrates the categorisation of the sector to which each participant belongs. Based on the available data, it is evident that a significant majority (73% of the respondents) engage in professional practise within the private sector. Conversely, a proportion of 26% of the respondents are involved in practise within the public sector, while a relatively smaller number of 1% of the respondents are found to be engaged in professional practise within the third sector. As the role of public-private partnerships within the sector have been emphasised in the literature review as a critical driver to the adoption of NZEBs in Nigeria, having a significant number of responses from these sectors will enhance the quality of this study.

1.3 In which of these categories does your years of experience in the industry fall under?

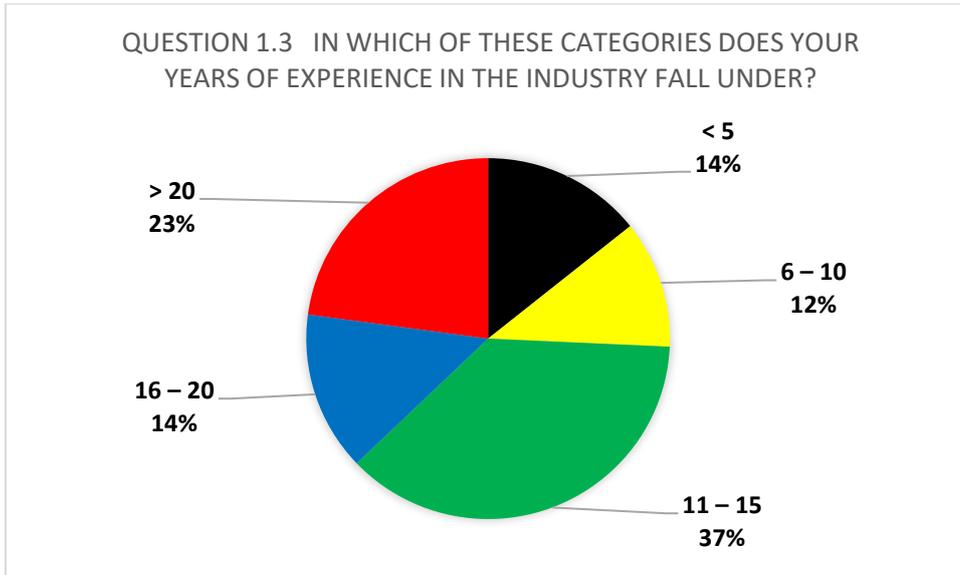


Figure 4.3: Years of industry experience of respondents

The data presented in Figure 4.3 indicates that respondents with 11–15 years of experience received the highest number of responses, accounting for 37% of the total. However, the data also reveals a diverse distribution of experience levels, ranging from 5 years or less to 20 years and above. This contributes to the overall improvement of the survey's quality. However, it is important to note that the architects in this study have a wealth of experience in the industry compared to other professions. Table 14. Given the significant role that architects play in the process of building procurement, their involvement is highly relevant and contributes to the advancement of this research.

Table 14: Building professionals and their years of experience.

		Building Professionals							
		Architect	Green Building Consultant Energy Expert	/	Others	Builder	Quantity Surveyor	Engineer	Total
Year	> 20	6	2	1	1	1	3	14	
	6 – 10	3	1	1	1	1	3	10	
	< 5	5	2	1	0	1	2	11	
	11 – 15	11	3	2	3	0	5	24	
	16 – 20	3	1	0	3	2	2	11	

Building Professionals							
	Architect	Green Building Consultant / Energy Expert	Others	Builder	Quantity Surveyor	Engineer	Total
Total	28	9	5	8	5	15	70

Table 14 shows data of building professionals and their years of experience

2. This section is related to you or your organisation’s experience with energy-efficient building project(s).

2.1 How familiar are you with Energy-Efficiency (EE)?

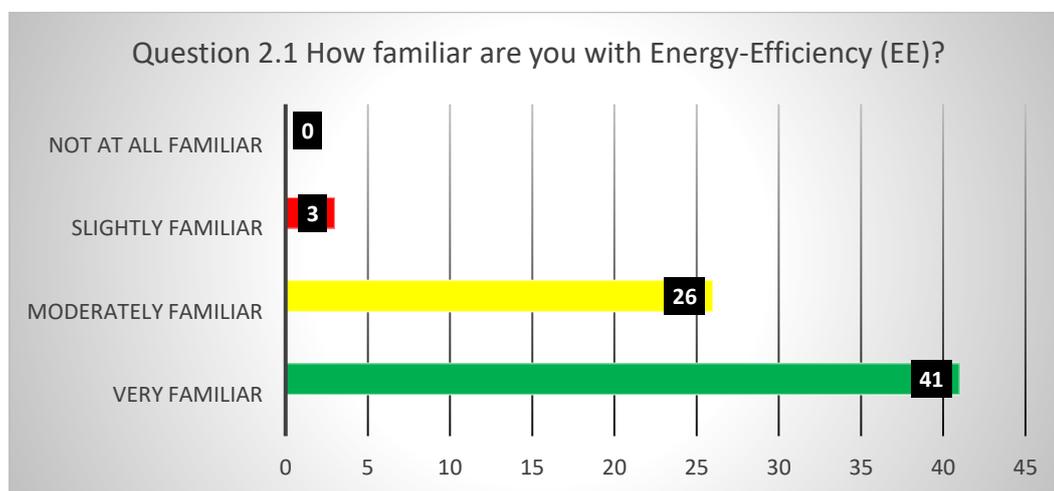


Figure 4.4: Respondents Familiarity of EE

Figure 4.4 illustrates the level of familiarity that respondents have with EE, as indicated by a range of alternatives ranging from 'Not At All Familiar' to 'Very Familiar'. Based on the data obtained, it is evident that a total of 41 respondents possess a high level of familiarity with EE. The aforementioned figure represents a substantial majority, amounting to 58.6% of the total. The data further indicates that 26 respondents and 3 respondents are 'Moderately Familiar' and 'Slightly Familiar' respectively. No respondents expressed a complete lack of familiarity with EE. This further strengthens the quality of the data retrieved from the survey. It places the findings from the survey questionnaire in a great position to inform the development of the proposed strategic roadmap for NZEB adoption in Nigeria.

2.2 How many Energy-Efficient Building Project(s) have you or your organisation been involved in?

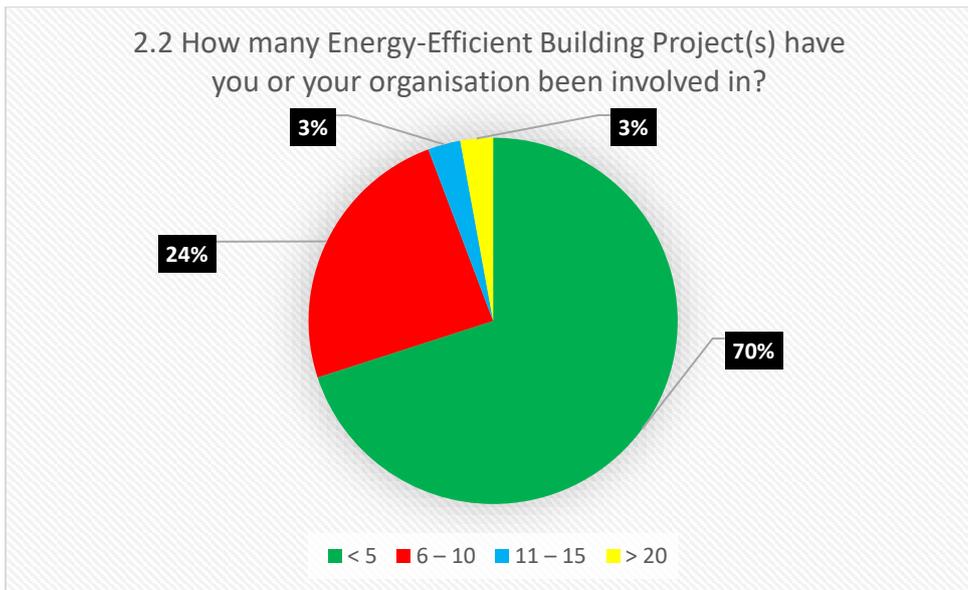


Figure 4.5: Number of EE building projects respondents have been involved in

Figure 4.5 demonstrates that a substantial majority, amounting to 70% of the respondents have displayed limited engagement with energy-efficient building (EEB) projects. The aforementioned percentage of respondents have reported their involvement in 5 or fewer EEB projects. A total of 24% of the respondents reported their involvement in 6–10 EEB projects, whereas 3% of the total responses indicated their participation in 11–15 EEB projects and 20 or more projects, respectively.

When examining the data from question 2.1, it becomes evident that while a significant proportion of respondents possess a high level of familiarity with EE, only a small minority have actively participated in EEB projects. The subsequent sections will provide data that will reveal what factors are responsible for this.

2.3. To what extent have you used the below National Building Energy Efficiency Code (NBEEC) interventions in building project?

2.3. To what extent have you used the below National Building Energy Efficiency Code (NBEEC) interventions in building project?

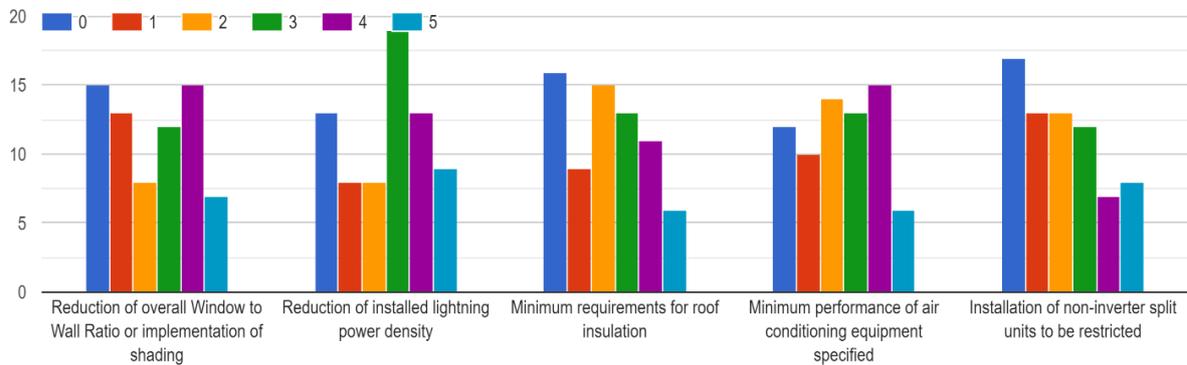


Figure 4.6: Extent of respondent's involvement with NBEEC interventions

Legend	Description
0	Not at all
1	A little
2	Somewhat much
3	Moderately Much
4	Much
5	Very much

In Q2.3, respondents were asked about their level of involvement with NBEEC interventions in building projects. Data retrieved as shown in figure 4.6 suggests that some NBEEC interventions such as Reduction of overall Window to Wall Ratio or implementation of shading, have been used to a moderate or relatively high extent in building projects by respondents, while other interventions such as Installation of non-inverter split units to be restricted, are used to a lesser extent. A deep dive into 'installation of non-inverter split units reveals that quantity surveyors and other professions not specified in the study, have applied this NBEEC intervention the least. It is evident architects have interacted more with EEB projects compared to other professionals in the industry. This points to the significant role architects play in the development of the proposed strategic roadmap.

Table 15: measures of central tendency

		%	Mean	Sum	Std. Deviation	Variance
Non-inverter split	Architect	43.62%	2.05	84	1.47	2.15

		%	Mean	Sum	Std. Deviation	Variance
unit						
	Engineer	23.4%	2.5	55	1.97	3.88
	Green Building Consultant / Energy Expert	9.57%	2	18	1.66	2.75
	Builder	9.57%	2.44	22	1.51	2.28
	Others	6.38%	1.5	9	1.64	2.7
	Quantity Surveyor	6.38%	1.83	11	1.83	3.37

Table 15 shows the measures of central tendency of the retrieved data from respondents

2.4 To what extent have you adopted Energy-Efficient strategy for the below categories?

2.4 To what extent have you adopted Energy-Efficient strategy for the below categories?

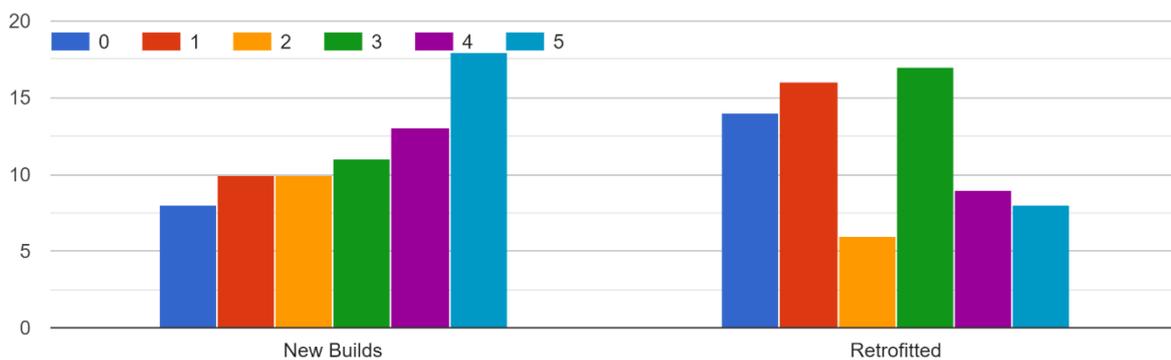


Figure 4.7: Extent of respondent's usage of EE strategy in new builds and retrofits

Legend	Description
0	Not at all
1	A little
2	Somewhat much
3	Moderately Much
4	Much
5	Very much

The data presented in Figure 4.7 illustrates the usage of EE strategies in new-build projects and retrofitting efforts, as reported by the respondents. The data indicates that a significant proportion of the respondents have extensively implemented EE strategies in new-build projects. A significant proportion of the participants, specifically 26%, have demonstrated a high level of adoption of EE practises in new-build projects. This is closely followed by 19% of respondents who have indicated

'Much' degree of adoption. The category with the lowest frequency is labelled "Not at all," indicating that a small number of respondents have not adopted the EE strategy in new builds. In contrast, a significant proportion (24% of respondents) have 'Moderately' implemented EE strategies in retrofit projects. Additionally, a noteworthy percentage of 23% and 20% of participants have implemented 'A little' EE strategy and have 'Not at all' implemented any strategy, respectively.

The data presented indicates that respondents exhibit greater levels of engagement in new-build projects as opposed to retrofits. This is vital as this research context is on new build, therefore the responses will be well aligned with the research aim.

2.5. To what extent have you used Energy-Efficient strategies in the below building types.

2.5. To what extent have you used Energy-Efficient strategies in the below building types. (Please indicate using the Likert scale where 0 = Not at all, 5 = Very Much)

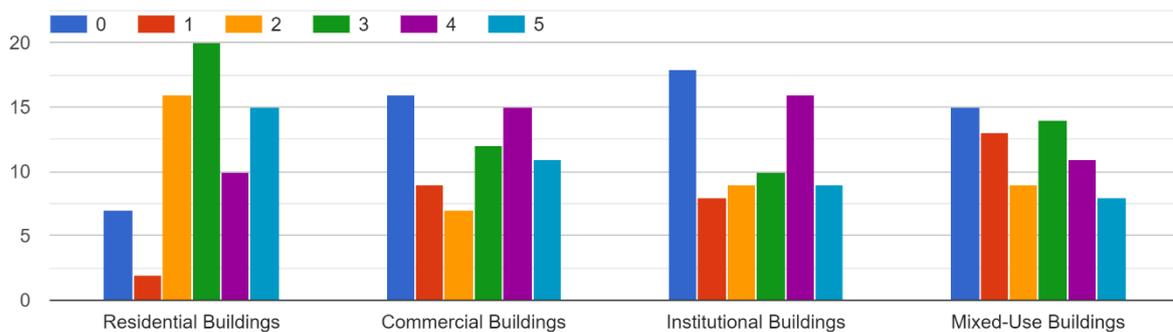


Figure 4.8: Extent of respondent's usage of EE strategy in various building types

Legend	Description
0	Not at all
1	A little
2	Somewhat much
3	Moderately Much
4	Much
5	Very much

Figure 4.8 shows data on the extent the respondents have applied energy-efficient strategies on residential buildings, commercial buildings, institutional buildings, and mixed-use buildings. Residential buildings recorded the highest number of responses across all building types, with 'Moderately much' being the most preferred choice. Table shows that building professionals have applied energy efficiency strategy the most on residential buildings. It further shows that Architects

have been the most involved across all categories of buildings. This section is particularly crucial as the study is based on residential buildings.

Table 16: Extent of Energy efficiency application on building categories

		%	Mean	Sum	Std. Deviation	Variance
Residential Buildings	Architect	43.62%	2.93	120	1.37	1.87
	Engineer	23.4%	3.41	75	1.53	2.35
	Green Building Consultant / Energy Expert	9.57%	3.33	30	1.8	3.25
	Builder	9.57%	3.56	32	1.33	1.78
	Others	6.38%	2.17	13	1.83	3.37
	Quantity Surveyor	6.38%	2.5	15	1.38	1.9
Institutional Buildings	Architect	43.62%	2	82	1.73	3
	Engineer	23.4%	2.95	65	1.99	3.95
	Green Building Consultant / Energy Expert	9.57%	2.33	21	2.18	4.75
	Builder	9.57%	3.22	29	1.48	2.19
	Others	6.38%	1.5	9	1.76	3.1
	Quantity Surveyor	6.38%	2.17	13	1.47	2.17
Commercial Buildings	Architect	43.62%	2.39	98	1.72	2.94
	Engineer	23.4%	3	66	1.95	3.81
	Green Building Consultant / Energy Expert	9.57%	2.78	25	1.86	3.44
	Builder	9.57%	3.44	31	1.42	2.03
	Others	6.38%	2	12	1.9	3.6
	Quantity Surveyor	6.38%	2.33	14	1.51	2.27
Mixed-Use Buildings	Architect	43.62%	2.05	84	1.61	2.6
	Engineer	23.4%	2.73	60	1.93	3.73
	Green Building Consultant / Energy Expert	9.57%	2.22	20	1.79	3.19
	Builder	9.57%	3.11	28	1.62	2.61
	Others	6.38%	2	12	1.67	2.8
	Quantity Surveyor	6.38%	2.33	14	1.51	2.27

3. This section is related to energy standards/Certifications.

3.1 How familiar are you with the following energy standards?

3.1 How familiar are you with the following energy standards?

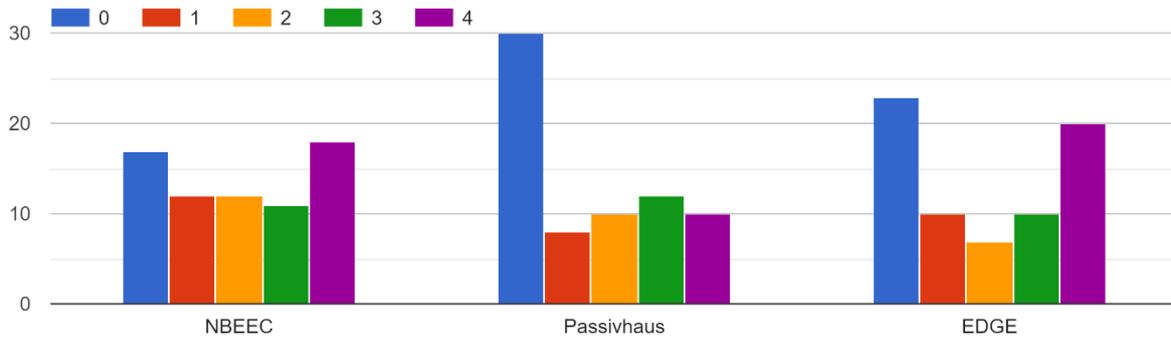


Figure 4.9: Respondents familiarity with key energy standards

LEGEND	DESCRIPTION
0	Not at all Familiar
1	A little Familiar
2	Moderately Familiar
3	Familiar
4	Very Familiar

Data in figure 4.9 shows that most of the respondents are not at all familiar with Passivhaus and EDGE. However, a significant number of respondents expressed very much familiarity with EDGE and NBEEC respectively. There appears to be a more balance of familiarity on NBEEC compared to Passivhaus and EDGE. This can be attributed to the fact that NBEEC is a local standard hence professionals are naturally inclined to be more familiar with it than with international standard.

3.2 Which of the following 'energy' standard/certification do you or your organization adopt in Energy-Efficient projects?

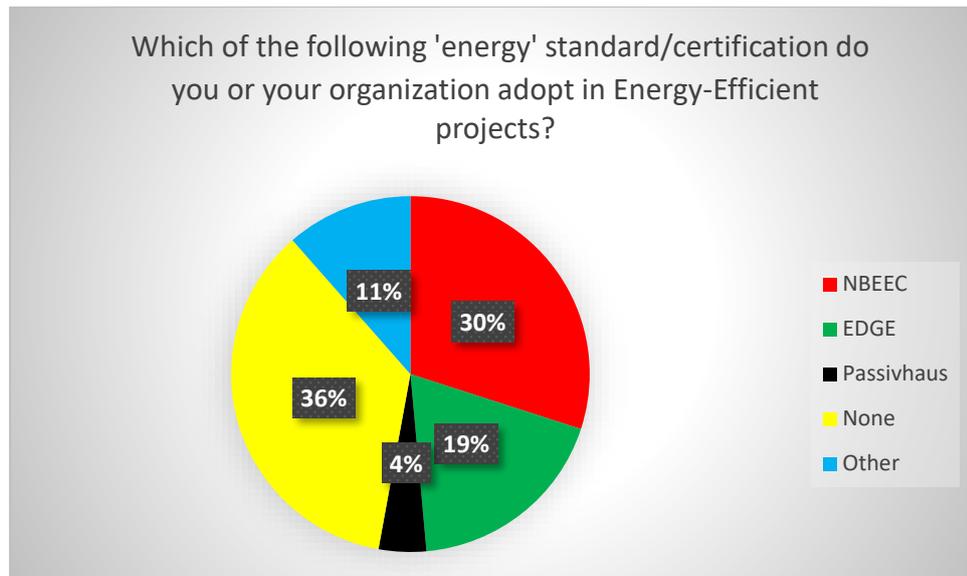


Figure 4.10: Energy standards adopted by respondents or their organisation.

According to the statistics presented in Figure 4.10, a significant majority of respondents, or their respective organisations, have not yet implemented any energy standard. The energy standard that has garnered the highest adoption rate among the respondents or their respective organisations is NBEEC, with a prevalence of 30%. The Passivhaus energy standard has been observed to have the lowest adoption rate, accounting for only 11% of the total.

A correlation is seen in Q3.1, as respondents demonstrated a higher level of familiarity with NBEEC and a lower level of familiarity with Passivhaus. There is discernible evidence that, despite the lack of widespread popularity of energy standards among experts, the local standard NBEEC has comparatively higher levels of popularity when compared to other energy standards.

4. This section is related to the barriers and drivers of Net-Zero Energy Buildings (NZEB).

4.1 Rank these key barriers to achieving NZEB in Nigeria in their order of importance.

4.1 Rank these key barriers to achieving NZEB in Nigeria in their order of importance.

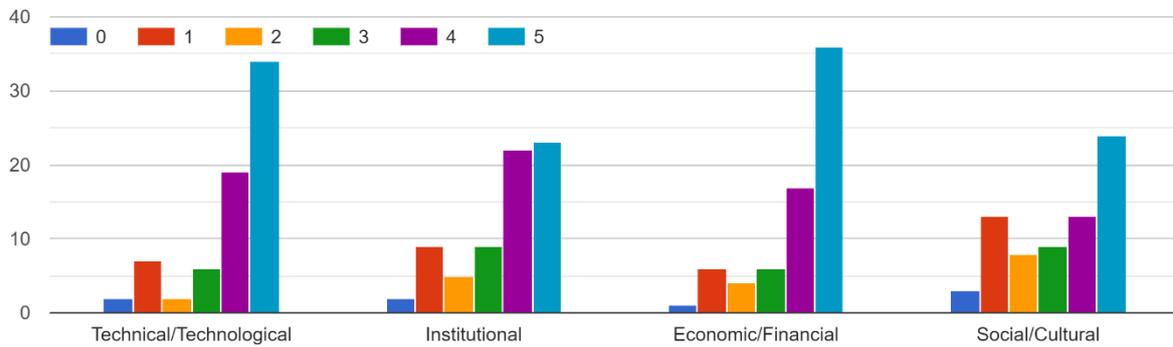


Figure 4.11: Ranking of key barriers in their order of importance

LEGEND	DESCRIPTION
0	Not at All Important
1	Slightly Important
2	Somewhat Important
3	Moderately Important
4	Very Important
5	Extremely Important

The data shown in Figure 4.11 provides clear evidence that a significant number of respondents acknowledged that the listed barriers have at least a moderate level of importance relative to the achievement of NZEB in Nigeria. The most frequently mentioned barriers by respondents are Technical/Technological and Economic/Financial barriers. Data indicates that for the categories of Extremely Important, Very Important, and Moderately Important, Technical/Technological and Economic/Financial barriers ranked the highest amongst respondents with each having 84.2% of the total response. Institutional barriers closely followed with 77.1%, while Social/Cultural barriers ranked the lowest with 65.7%.

Below is a breakdown of the analysis within each category.

Technical/Technological Barrier

When asked to rank the listed key barriers to achieving NZEB in Nigeria in their order of importance as seen in figure 4.11, 75% of respondents agreed that technical/technological barrier is either extremely important or very important. Extremely important make up the

majority of that percentage. A very minimal percentage of 3% each agreed that technical/technological is Not at All Important and Somewhat Important.

Institutional

The two most popular choices amongst respondents for this category are Extremely Important and Very Important with a percentage of 33% and 31% percent respectively. Not At All Important ranked the lowest with a minimal percentage of 3%.

Economic/Financial

At least 51% of respondents agreed that Economic/Financial barriers are Extremely Important as a key barrier in achieving NZEB in Nigeria. The next popular choice for this category is Very Important with 24% of the responses. The least choice was 1 percent, with only 1 response acknowledging that economic/financial barrier is Not at All Important.

Social/Cultural

Majority of the respondents with 34% of the responses agreed that social/cultural barrier is an Extremely Important barrier in achieving NZEB in Nigeria. Similar percentage of 19% respectively, picked either Very Important or Slightly Important. While Moderately Important and Slightly Important had a 13% and 11% of the responses respectively. The list choice is Not at All Important with 4% of the respondents opting for this choice.

A two-factor Analysis of Variance (ANOVA) was carried out to test the null hypothesis: There is no significant difference between the groups of the first factor Technical / Technological and Economic / Financial (measurement repetition) in relation to the dependent variable. There is no significant difference between the groups of the second factor Building Professionals in relation to the dependent variable.

Table 17: ANOVA (Two-Factor) Test Result

	Sum of squares	df	Mean Squares	F	p
Technical / Technological, Economic / Financial	0.19	1	0.19	0.3	.587
Building Professionals	9.63	5	1.93	0.59	.709
A x B	8.05	5	1.61	2.47	.039
Between	294.66	92	3.2		
Within the sample	285.02	87	3.28		
Residuum	56.76	87	0.65		
Within	65	93	0.7		
Total	359.66	185	1.94		

Interpretation Of ANOVA Test.

A two-factor analysis of variance with measurement repetition was performed to test whether there was a significant difference between the groups of the first factor " Technical / Technological and Economic / Financial " (repeated measures) with respect to the dependent variable, a significant difference between the groups of the second factor Building Professionals in relation to the dependent variable, and there is an interaction between the two factors " Technical / Technological and Economic / Financial " and Building Professionals in relation to the dependent variable.

The two-factor analysis of variance with repeated measures showed that there is no significant difference between the groups of the first factor " Technical / Technological and Economic / Financial " in relation to the dependent variable, $p=0.709$. This means that there is no significant difference between the mean values of the dependent variable when considering the "Technical/Technological" and "Economic/Financial" groups. The main effect of the factor "Building Professionals" is also not statistically significant ($p = 0.709$). This suggests that there is no significant difference in the mean values of the dependent variable across the different groups of building professionals. However, the interaction effect between the two factors ("Technical/Technological and Economic/Financial" \times "Building Professionals") is statistically significant ($p = 0.039$). This implies that the difference in the mean values of the dependent variable between the "Technical/Technological" and "Economic/Financial" groups depends on the specific group of building professionals.

Implication of ANOVA test for Study

The implications of these findings for the study are as follows:

The lack of a significant main effect for the "Technical/Technological and Economic/Financial" factor suggests that, on average, there is no difference in the perceptions, ratings, or rankings (depending on the dependent variable) between the technical/technological and economic/financial aspects of the study. This could indicate that these aspects are perceived as equally important or challenging in achieving NZEBs in Nigeria.

The lack of a significant main effect for the "Building Professionals" factor suggests that, on average, there are no substantial differences in the perceptions, ratings, or rankings among the different groups of building professionals (e.g., architects, engineers, consultants, etc.) regarding the dependent variable.

The significant interaction effect suggests that the differences in perceptions, ratings, or rankings between the "Technical/Technological" and "Economic/Financial" aspects vary depending on the specific group of building professionals. In other words, different groups of building professionals may have different perspectives or priorities when it comes to the technical/technological versus economic/financial aspects of achieving NZEBs in Nigeria.

Overall, the significant interaction effect highlights the importance of considering the perspectives of different building professionals when developing strategies or policies related to achieving NZEBs in Nigeria, as their priorities or perceptions may vary depending on their professional backgrounds and experiences.

4.2 Rank these key technical/technological barriers to achieving NZEB in Nigeria in their order of importance.

4.2 Rank these key technical/technological barriers to achieving NZEB in Nigeria in their order of importance. (Please indicate using the Likert scale where 0 = Not Important; 5 = Extremely Important)

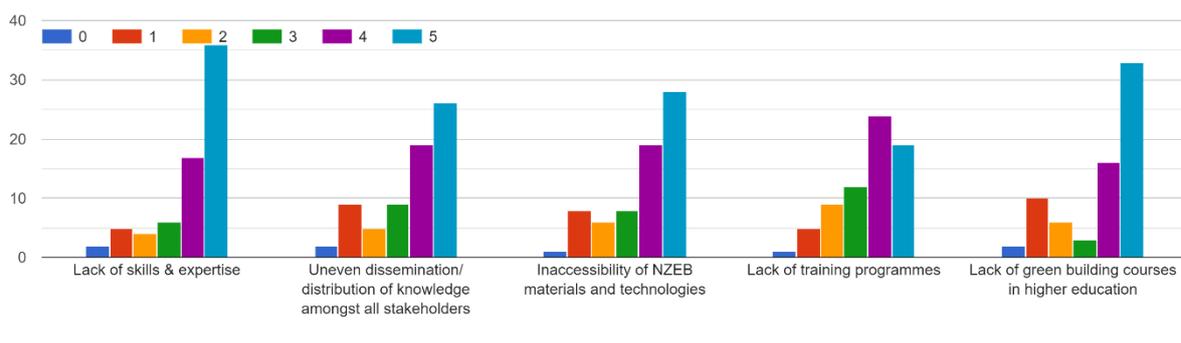


Figure 4.12: Ranking of key technical/technological barriers in their order of importance.

LEGEND	DESCRIPTION
0	Not at All Important
1	Slightly Important
2	Somewhat Important
3	Moderately Important
4	Very Important
5	Extremely Important

Figure 4.12 depicts a ranking of key technical/technological barriers that hinder the achievement of NZEB in Nigeria based on their respective levels of importance. The data shows Lack of skills & expertise as the most popular choice amongst respondents. For the technical/technological barriers which are either Extremely Important, Very Important, or Moderately Important, the data indicates

that with 84.2%, Lack of skills & expertise ranks the highest, Inaccessibility of NZEB materials and technologies, and Lack of training programmes ranks 2nd with 78.5%, respectively. Uneven dissemination/distribution of knowledge amongst all stakeholders ranked 4th with 77.1%, while Lack of green building courses in higher education ranked the least with 74.2%. Overall, the data shows that all key technical/technological barriers to achieving NZEB in Nigeria were significantly considered to be at the very least Moderately Important.

4.3 Rank these key institutional barriers to achieving NZEB in Nigeria in their order of importance.

4.3 Rank these key institutional barriers to achieving NZEB in Nigeria in their order of importance.

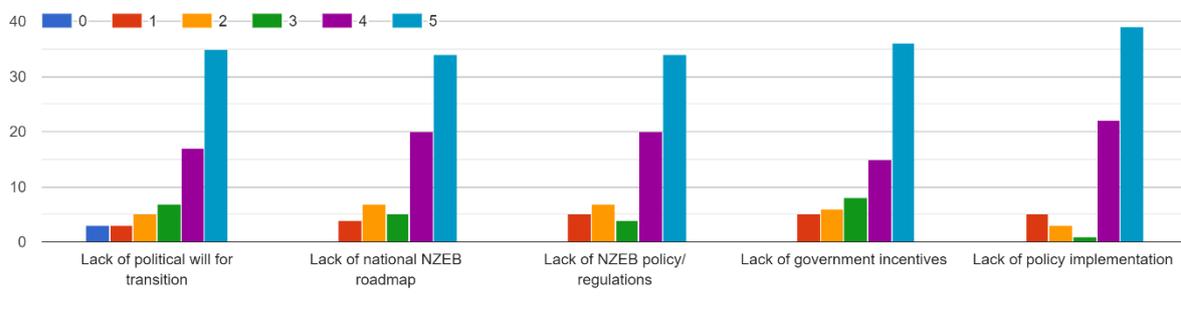


Figure 4.13: Ranking of key institutional barriers in their order of importance.

LEGEND	DESCRIPTION
0	Not at All Important
1	Slightly Important
2	Somewhat Important
3	Moderately Important
4	Very Important
5	Extremely Important

Figure 4.13 presents the ranking of key institutional barriers that impede the attainment of NZEB in Nigeria in order of importance. The data unequivocally demonstrates that the option labelled "Extremely Important" was the prevailing choice across all categories of institutional barriers. For the institutional barriers that are either Extremely Important, Very Important, or Moderately Important, Lack of policy implementation ranked the highest with 88.5%; Lack of political will for transition; Lack of a national NZEB roadmap; and Lack of government incentives all ranked 2nd with 84.2%, respectively. Lack of NZEB policy/regulations was ranked the least with 82.8%. Overall, the data clearly justifies Chapter 2 (the literature review) of this thesis.

4.4 Rank these key economic/financial barriers to achieving NZEB in Nigeria in their order of importance.

4.4 Rank these key economic/financial barriers to achieving NZEB in Nigeria in their order of importance.

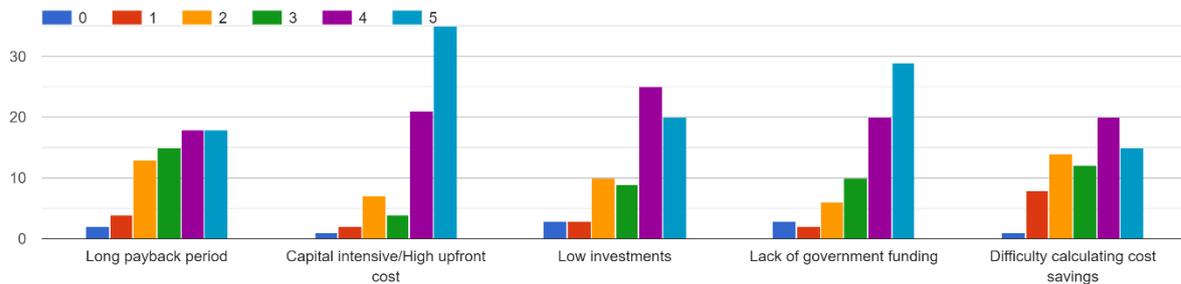


Figure 4.14: Ranking of key economic/financial barriers in their order of importance.

LEGEND	DESCRIPTION
0	Not at All Important
1	Slightly Important
2	Somewhat Important
3	Moderately Important
4	Very Important
5	Extremely Important

Figure 4.14 presents the ranking of key economic/financial barriers that hinder the achievement of NZEB in Nigeria. The data indicates that Capital Intensive is Extremely Important, as it emerged as the most preferred choice among the respondents. When ranked based on choice between Extremely Important, Very Important, or Moderately Important, Capital Intensive also ranked the highest with 85.7% amongst other categories of economic/financial barrier types. Lack of Government Funding ranked close 2nd with 84.2%, followed by Low Investments and Long Pay Back Period with 77.1% and 72.8%, respectively. Difficulty Calculating Cost Savings ranked the least with 67.1%, respectively. Overall, these key economic/financial barriers to achieving NZEB in Nigeria were viewed by a significant majority as being at the very least Moderately Important.

4.5 Rank these key social/cultural barriers to achieving NZEB in Nigeria in their order of importance.

4.5 Rank these key social/cultural barriers to achieving NZEB in Nigeria in their order of importance.

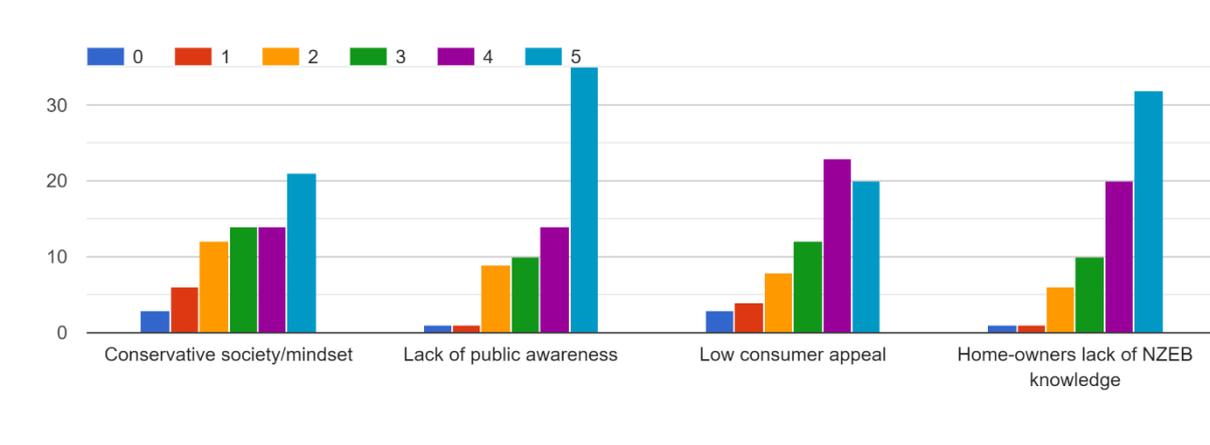


Figure 4.15: Ranking of key social/cultural barriers in their order of importance.

LEGEND	DESCRIPTION
0	Not at All Important
1	Slightly Important
2	Somewhat Important
3	Moderately Important
4	Very Important
5	Extremely Important

Figure 4.15 shows the ranking of the key social/cultural barriers to achieving NZEB in Nigeria in their order of importance. Based on the available data, it can be observed that the category of 'Extremely Important' is the preferred choice across all categories, with the exception of 'Low consumer appeal', where the popular choice is identified as Very Important. When ranked based on a choice of either Extremely Important, Very Important, or Moderately Important, Homeowners' lack of NZEB knowledge ranked the highest amongst other social/cultural barriers with 88.5%. Lack of public awareness ranked 2nd with 84.2%, Low consumer appeal ranked 3rd with 78.5%, and Conservative society/mindset ranked the least with 70%.

4.6 Rank these key drivers of NZEB in Nigeria in their order of importance.

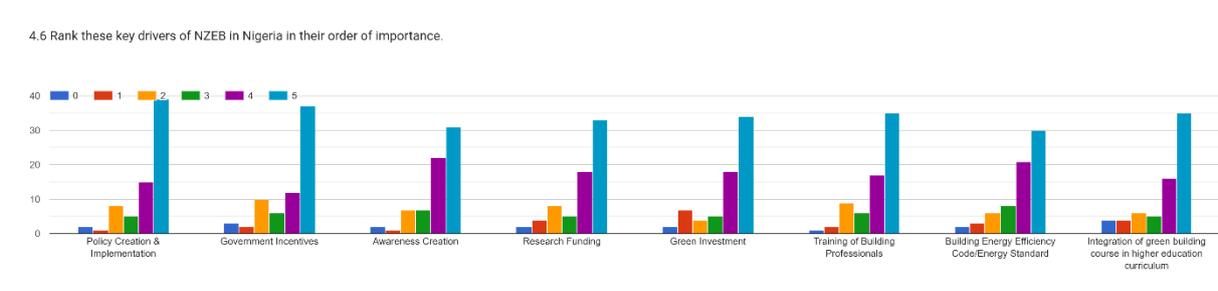


Figure 4.16: Ranking the key drivers of NZEB in Nigeria in their order of importance.

LEGEND	DESCRIPTION
0	Not at All Important
1	Slightly Important
2	Somewhat Important
3	Moderately Important
4	Very Important
5	Extremely Important

Figure 4.16 shows the ranking of key drivers of NZEB in Nigeria in order of importance. Based on the available data, it can be observed that the option labelled "Extremely Important" has the highest level of popularity among all key drivers, surpassing other choices by a significant margin. The highest-rated driver, based on 39 respondents who deemed it Extremely Important, was Policy Creation & Implementation. Government incentives were put closely behind the top response, receiving 37 responses. The Training of building professionals and the Integration of Green building courses in higher education curriculum were tied for third place, each receiving 35 responses. Green Investment was placed next, receiving a total of 34 responses. On the other hand, Research Funding secured the sixth position with 33 responses. The category of Awareness Creation had the 7th highest ranking, with a total of 31 responses. In contrast, the Building Energy Efficiency Code/Energy Standard category received the lowest ranking, with only 30 responses.

Table 17: ANOVA with repeated measures test

	Type III Sum of Squares	df	Mean Squares	F	p
Treatment	2.99	2	1.49	3.11	.047
Within	91.33	186	0.49		
Error	88.34	184	0.48		

Interpretation Of ANOVA Test.

The one-factor repeated measures ANOVA was conducted to test if there were significant differences in the rankings of the key drivers of NZEB in Nigeria, specifically focusing on the three drivers: "Policy Creation & Implementation," "Government Incentives," and "Awareness Creation."

The ANOVA results show a statistically significant difference among these three drivers ($F(2, 184) = 3.11, p = 0.047$). This means that the null hypothesis, which stated that there is no difference between these dependent variables, can be rejected.

The significant ANOVA result implies that the respondents perceived the importance of these three drivers differently when ranking them in order of importance for achieving NZEBs in Nigeria.

These observations suggest that the respondents perceived "Policy Creation & Implementation" and "Government Incentives" as more important drivers for achieving NZEBs in Nigeria compared to "Awareness Creation."

Implication For Study

The implications of these findings for the study are:

Developing and implementing policies related to NZEBs should be a top priority for stakeholders and decision-makers in Nigeria, as it is perceived as the most critical driver by the respondents.

Providing government incentives, such as financial incentives or tax credits, is also considered highly important and should be considered as part of the overall strategy for promoting and achieving NZEBs in Nigeria.

While "Awareness Creation" is still considered important, it may not be perceived as crucial as the other two drivers. However, it should not be overlooked, as raising awareness and educating various stakeholders (e.g., building professionals, homeowners, policymakers) can play a vital role in the successful adoption and implementation of NZEBs.

Overall, the study's findings highlight the importance of a multi-faceted approach that combines policy development, government incentives, and awareness creation efforts to effectively drive the transition towards NZEBs in Nigeria.

5. What recommendation(s) would you provide for achieving NZEB in Nigeria?

The purpose of this section was to afford respondents the chance to express their perspectives on achieving NZEB in Nigeria, which might not have been addressed in the survey questionnaire or require further elaboration. Among the total of 70 responses received, it was observed that 30

respondents provided comments in this section. The remarks provided by participants were synthesised and subsequently categorised into different themes.

- a) Policy creation and implementation: The development and implementation of policies are considered crucial by respondents for achieving NZEB in Nigeria. This, according to the responses, is because policies serve as the fundamental framework upon which other drivers can be established.
- b) Awareness creation & Education: Conduct awareness campaigns via mainstream media, social media platforms, workshops, seminars, and similar avenues to efficiently disseminate knowledge and foster a wider understanding of the value and benefits of NZEBs. Furthermore, it is suggested that the integration of NZEB concepts be incorporated as a component within the curriculum of higher education programmes in architecture and other relevant disciplines. This would serve to equip aspiring professionals within the sector with the necessary knowledge and skills to effectively engage in sustainable building design and construction practises.
- c) Financial incentives: Financial incentives should be provided by governments to homeowners and developers to promote the adoption of NZEB. These incentives may encompass financial assistance provided in the form of subsidies to offset the initial expenses.
- d) Capacity Building: Capacity building involves the development of training programmes that prioritise the concept and principles of NZEB, energy-efficient design techniques, renewable energy sources, and building performance. This initiative will foster the development of a skilled workforce, strengthen institutional capacities, and establish an enabling environment to facilitate the widespread adoption of NZEB.
- e) Collaboration and Partnership: According to the responses, a collective effort that involves knowledge and resource sharing will facilitate action to transition to NZEB.

The remarks made in Section 5 regarding the recommendations for achieving NZEB align closely with the study findings thus far.

4.3 Expert Interview

As discussed in chapter 3, 6 green building experts in Nigeria were interviewed based on a set of criteria. The purpose of this interview is to compliment the survey questionnaire and tease out key information from the findings of the survey questionnaire, which will help in answering the research questions and aim of the study. The expert interview was administered via telephone as this was what all participants deemed convenient. Analysis of the expert interview were discussed under three main predetermined themes developed from the research questions. Subsequently, sub-themes were

developed following the processing of the interview data. R was used to represent ‘Respondent’, by so doing protecting the identities of the participants. Table 18.

Table 18: Demographic Information of Experts

Expert ID	Geo-Political Zone	Years of Experience	Area of Expertise
R1	South-South	15+ years	Sustainable and energy-efficient building practices, renewable energy integration
R2	North-Central	12+ years	Green building design, energy-efficient strategies
R3	South-West	18+ years	Sustainable building materials, EDGE certification Expert
R4	North-East	10+ years	Energy-efficient construction, regulatory compliance
R5	South-East	14+ years	Green building policies, international collaborations and publications on energy-resource efficiency
R6	North-West	16+ years	EDGE certification Expert, Policy maker, NZEB design

Table 18 shows the demographic information of experts

Table 19: Development of the expert interview analysis

Research Questions	Themes	Sub - Themes
What are the key barriers to achieving NZEBs in Nigeria?	Barriers	Developed from the interview data on Barriers.
What are the key drivers of NZEBs in Nigeria?	Drivers	Developed from the interview data on Drivers.
How can a strategic roadmap be developed to guide the transition towards Net-Zero Energy in residential buildings in Nigeria by 2060?	Strategic Roadmap	Developed from the interview data on strategic roadmap.

Table 19 shows how the expert interview thematic analysis was informed. Three predetermined themes were informed by the research questions on barriers, drivers and strategic roadmap, and sub-themes were developed following the processing of the interview data under the main themes.

Barriers – level of involvement

The questions asked in relation to this theme can be found in the appendix. The purpose of this theme is to understand the barriers responsible for the limited participation of building construction professionals in EEB projects as exposed in the findings of the survey questionnaire. This section is crucial to delve deep into the issues regarding NZEB adoption in Nigeria. The analysis of this section is presented under five sub-themes: lack of market demand, limited expertise, information gap, supply chain challenges, and lack of incentives.

- **Lack of Market Demand:** This was a reoccurring theme amongst some of the respondents. Responses from the respondents showed that lack of market demand is responsible for the limited involvement of the survey questionnaire participants in EEB projects.

“There must be a strong market demand of these kinds of projects first, before professionals can get involved. A lot of clients don’t prioritise energy efficiency for several reasons, hence professionals are left no choice but to work on conventional projects” – R2.

“These professionals have not had the opportunity to work on such projects as the demand for green buildings is relatively low in the country” – R5.

Going by the views of R2 and R5, it is evident that the demand for EEB projects would drive the supply of building professionals’ services. Therefore, the government needs to incentivise the sector to create an enabling environment.

- **Limited Expertise:** R3 and R4 stated that the lack of expertise on EEB is responsible for the limited participation of building construction professionals on EEB projects.

“Most of these professionals are really not skilled in this field” – R3.

“They lack the technical-know-how to be involved in these kinds of project, therefore, this presents a major challenge” – R4.

The views of R3 and R4 validates one of the findings from the literature review and survey questionnaire regarding the barriers to the adoption of NZEBs in Nigeria.

- **Information Gap:** some of the respondents noted the gap in information on EEBs as a major issue that could be responsible for this lack of involvement from building professionals. As regards this information gap, R4 referenced the building professionals and pointed out the need for continuing professional development (CPD) to help address this gap.

“Some building professionals even though have the basic knowledge of EEBs, don’t fully understand the benefits especially on the long-term, associated with EEBs, and how to access them, hence they stick with familiar practices” – R1.

“Most building professionals are not well grounded in this field, hence their lack of involvement. CPDs that increases the level of knowledge and experience on EEB should be made compulsory if this is to be addressed” - R4.

R6 referred to clients as lacking comprehensive information on EEB hence opt for conventional buildings.

“I have noticed a massive gap in information on the part of the clients.

This is a big issue at the moment as the clients drives the market demand”. – R6.

Following the views of R1, R4 and R6, it is evident that there is limited knowledge among stakeholders in the sector. This is one of the factors that have limited the involvement of building professionals in EEB projects. CPDs for building professionals and client education is one of the suggestions from the study findings to help address this issue.

- **Supply Chain Challenges:** There was consensus among the respondents on this topic. They all pointed out the difficulties involved in sourcing EEB materials has over the years discouraged a lot of building professionals from committing to EEB projects.

“Materials and technologies for these kinds of project are not readily available, In fact, a lot of these materials and technologies are imported” – R1.

“There is a huge supply chain challenge for EEB projects. Materials for the construction and maintenance of these types of projects are usually very difficult to source locally” – R2.

“Nigeria doesn’t have a lot of local manufacturers of EEB materials and technologies, therefore, it poses a difficult challenge for developers to access them. The limited number of EEB projects by developers necessitates a limited participation of building professionals in these kinds of projects” – R5.

Views from R1, R2, and R5 demonstrates that the difficulty in sourcing EEB materials and technologies has led to the huge deficit in building professionals’ involvement in EEB projects.

- **Lack of Incentives:** responses from the experts revealed that the lack of incentives such as financial incentives and technical support, and tax breaks has made it difficult for building professionals to get involved in EEB projects.

“The Nigerian government does not view EEB projects as a priority in the country, hence why financial incentives are difficult to come by for developers” – R2.

If developers are discouraged from developing EEB projects due to lack of incentives, building professionals would find it difficult to get involved.

To increase the level of involvement in EEB projects, addressing this topic from the expert interview may require several policy changes that integrates CPDs, client education, public awareness campaigns and financial incentives. This will create an enabling environment for energy-efficient construction practices.

Drivers - creation of a green building database / built environment carbon database.

The purpose of this theme is to explore how one of the recommendations – creation of a green building database / built environment carbon database – can be implemented to accelerate the adoption of NZEB. This section

This section is crucial to delve deep into the issues regarding NZEB adoption in Nigeria. The analysis of this section is presented under four sub-themes: data collection and standardisation, collaboration, awareness campaigns, and policy integration. The questions asked in relation to this theme can be found in the appendix.

- **Data Collection and Standardisation:** Some of the responses suggested that the collection of comprehensive data on newly constructed building is a starting point for the implementation of a green building database.

“Data should be collected on energy consumption, materials used, construction methods, and carbon emissions of newly constructed residential buildings. This will aid the implementation of a green building database” – R4.

This response will inform the development of the proposed strategic roadmap which is the aim of this study.

- **Collaboration:** R2 and R6 suggested that a collaboration between the government and building professionals can help set up a green building database.

“The government and professionals in the industry should collaborate to develop a green building database” – R2.

“A green building database can only be achieved with the collaboration

of the government and the stakeholders in the industry” - R6.

This response further strengthens the case that collaboration is crucial to the adoption of NZEB in Nigeria.

- **Awareness Campaigns:** The participants all emphasised the need for public awareness on green building database. This database will integrate various data on building energy consumption in Nigeria.

“The public needs to be adequately informed on the need for such database.

This can also facilitate data gathering. Lots of resources needs to be put

towards campaigns that raise the level of awareness on these subjects” – R3.

Public awareness according to the green building experts, is an essential if NZEB status is to be achieved by the year 2060.

- **Policy Integration:** R5 made a case for the need for policy integration to facilitate the development of a green building database. R5 further stated that the government has crucial role to play for this to be feasible.

“The government should integrate the green building database into

building codes and regulations. NZEB requirements in the country,

can be tied to data from the green building database” – R5.

By effecting the responses from the interview on the implementation of a green building database, Nigeria will not only accelerate its adoption of NZEBs, but will also attain a sustainable urban development.

Strategic Roadmap

The purpose of this theme is to identify the key issues that must be addressed in the proposed strategic roadmap. This section is of utmost importance as it is directly linked to the aim of this research. The analysis of this section has been presented under five sub themes. The questions asked in relation to this theme can be found in the appendix.

- **Capacity Building:** Responses from the experts showed that there is a need for capacity building to be integrated in the proposed strategic roadmap. They discussed capacity building as a critical component in achieving NZEB in Nigeria. They further stated that various stakeholders, including architects, engineers, contractors, policymakers, and the general workforce should be offered comprehensive training programs and workshops.

“As part of the roadmap to achieving NZEB, professionals in the industry

should be given adequate training on NZEB. This training should be continuous, and should cover the principles of NZEB design, energy-efficient building strategies, renewable energy integration, and sustainable building materials” – R2.

The response from R3 was hinged on IFC’s EDGE program - which was discussed in the literature review and findings from the case study. R3 recognised how this program has transformed similar markets globally and recognised the existence of this program in the country, however suggested that more should be done if Nigeria is to achieve complete decarbonisation in the sector by 2060.

“There is an existing collaboration between the Nigerian government and IFC which currently trains building professionals on the use of the EDGE software. Similar collaboration has completely transformed the building sector in other emerging economies. However, this has not been the case in Nigeria. For Nigeria to experience such industry transformation as seen in other countries; this needs to be advanced and properly implemented” – R3.

R4 suggested that curriculum integration needs to be addressed in the strategic roadmap to ensure future building professionals such as architects are well-prepared at the early stage of their careers.

“The policy makers need to collaborate with educational institutions to integrate NZEB concepts into their curricula, that way future architects, engineers and other building professionals are well grounded from the beginning stage of their careers” – R4.

From the responses of these green building experts, it is evident that capacity building is fundamental to creating a skilled workforce and a supportive ecosystem that can drive the successful implementation of NZEBs in Nigeria.

- **Research and Development:** R1 suggested that research and development should be integrated in the strategic roadmap. R1 further stated that the Nigerian government should invest in research and development that is aimed at NZEB technologies.

“The proposed roadmap should include investment by the Nigerian government in research and development that is focused on NZEB

technologies and practices” – R1.

- **Collaboration and Partnerships:** Responses from the experts alluded to the fact that collaboration and partnerships are essential ingredients in achieving NZEB as they pull resources together, encourage diverse perspectives and expertise., therefore should be integrated in the proposed strategic roadmap.

“Collaboration and partnerships are essential to achieving the 2060 decarbonisation status in the sector. This must be addressed in the roadmap” – R3.

“The Nigerian government should seek partnerships with global experts and organisations for knowledge sharing and capacity building” -R5.

“The sector needs a collaboration between the government, industry, academia, and international organisations. This should be included in your proposed roadmap” – R6.

The role of collaboration and partnership in achieving NZEB cannot be overemphasised as findings from the literature review, survey questionnaire, case study and expert interview has all identified this as a key driver.

- **Public Awareness:** There was a consensus from the experts on public awareness as an essential component that should be addressed in the proposed strategic roadmap.

“The government should launch a nationwide awareness campaign on NZEB. This would help educate the public about the benefits of NZEB. This should be one of the first things that should be addressed in the roadmap as it lays a solid foundation” – R1.

“There is a huge knowledge gap in Nigeria as regards sustainability practices let alone NZEB. With a large population, it presents an uphill task. A robust campaign on sustainability practices that captures the benefits of environmental sustainability are an essential to achieving NZEB in Nigeria” – R5.

Public awareness has been a reoccurring theme throughout this study as seen in the literature review, findings from the survey questionnaire, case study and the expert interview. It is therefore evident that public awareness is an essential component that should be included in the proposed strategic roadmap.

- **Regulatory Compliance:** Some of the responses from the experts alluded to the fact that there is no existing mechanism for monitoring and enforcing compliance with green building regulations. Therefore, this should be addressed in the strategic roadmap.

“There should be an established mechanism for monitoring and enforcing compliance with green building regulations, and penalties for non-compliance should be implemented to ensure accountability. At the moment, this does not exist, therefore should be addressed in the roadmap” – R4.

Following the interview with R4, it is evident that regulatory compliance is a foundational element in the transition toward NZEBs. If implemented and enforced, Nigeria can be well on track to achieving its 2060 target.

A strategic roadmap that incorporates these key issues will be essential for Nigeria to achieve its NZEB goals by 2060.

4.4 Chapter Summary

This chapter provided an overview of the results and findings derived from the survey questionnaire, case study, and expert interview. The following chapter presents the discussion and proposal.

CHAPTER 5: DISCUSSION AND PROPOSAL

5.1 Chapter Introduction

This chapter presents a synthesis of the findings from a comprehensive review of relevant literature, and a meticulous data analysis. These findings are then consolidated and aligned with the research questions posed in this study. Furthermore, significant findings from the collected data and the development of the proposed NZEB roadmap, which is the focus of this study, were discussed, as is the need for the proposed NZEB roadmap and its validation. Finally, this chapter discusses the researchers' interpretation of the findings from the data analysis of the literature reviewed in response to the aim of the research, which is to develop a strategic roadmap for achieving Net Zero Energy in residential buildings in Nigeria.

5.2 The current state of NZEBs in Nigeria

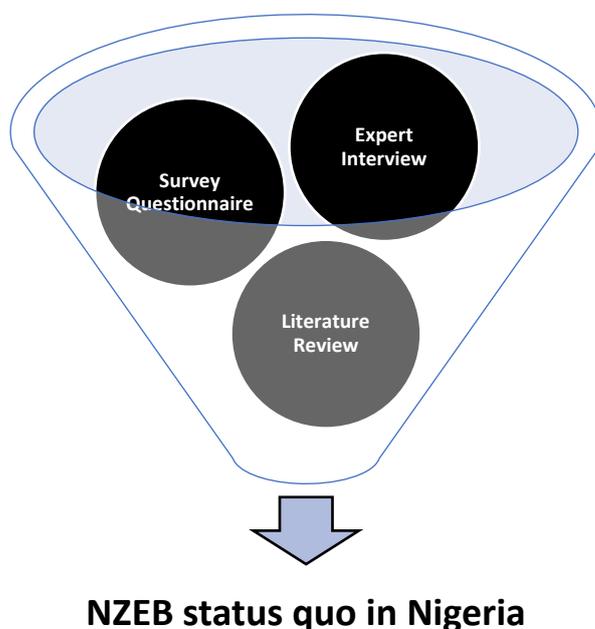


Figure 5.1: Identification process of NZEB status quo

Figure 5.1 illustrates the process of identifying the status quo of NZEB in Nigeria through the synthesis of finding from the literature review, survey questionnaire, and expert interview.

By conducting an extensive literature review, this study revealed the current state of NZEBs in Nigeria. Building upon the existing literatures such as (Iwuagwu and Onyegiri, 2019; Kang, *et al.*, 2022), a survey questionnaire and an expert interview were employed to investigate the issue further, therefore enhancing comprehension and insight into the current state of affairs. The study's findings indicate that NZEB is increasingly gaining recognition globally as a viable and sustainable approach to

addressing the climate catastrophe. However, its implementation in Nigeria is still in its infancy and is yet to become a mainstream concern within the political sphere. This limited implementation of NZEBs in Nigeria aligns with findings by (Iwuagwu and Onyegiri, 2019; Oyedepo *et al.*, 2020; Smith *et al.*, 2022), who noted that many developing countries face similar challenges in adopting advanced energy-efficient building practices. The quantity of already-existing NZEBs within the country is quite limited, particularly in comparison to conventional buildings. This reflects a broader trend observed in emerging economies as Akinwolemiwa and De Souza (2018) pointed out. The condition of residential structures in Nigeria is deeply concerning, characterised by a significant degree of energy consumption. This can be attributed to various factors, including the absence of comprehensive policies, regulatory frameworks, and effective implementation, among other contributing elements. This finding corroborates the work of Ezema *et al.* (2016), who identified weak regulatory frameworks, ineffective implementation of policies, and lack of energy-conscious behavior as key contributors to high energy consumption in Nigerian buildings. It is imperative to acknowledge that significant endeavours have been undertaken in terms of policy and collaborative initiatives in order to advance the achievement of NZEBs. These initiatives encompass the development of energy efficiency and renewable energy policies, such as the NESP, facilitated by the German government in partnership with Nigerian agencies. The primary objective of this programme is to encourage energy efficiency measures in all sectors, particularly the building sector. Additionally, the NREEEP has been formulated to provide a comprehensive framework for promoting renewable energy and energy-efficient practises across various sectors, including the building sector. Nevertheless, it should be noted that these policies and regulations are not exclusive to NZEBs. This observation is consistent with Dioha and Kumar's (2020) analysis of energy policies in Nigeria, which highlighted the need for more targeted policies to promote NZEBs specifically. Moreover, it is worth mentioning that there are several NZEB projects, with one notable example being the Solar Pavilion located in Eko Atlantic City. This particular project showcases the integration of energy-efficient design principles with the use of renewable energy systems. However, as Akande *et al.* (2021) argue, such showcase projects need to be scaled up and replicated across the country to make a significant impact on the building sector's energy consumption.

In summary, the present status of NZEBs in Nigeria serves as a compelling rationale for the significance and relevance of this research.

5.3 Key Barriers to achieving NZEB in Nigeria

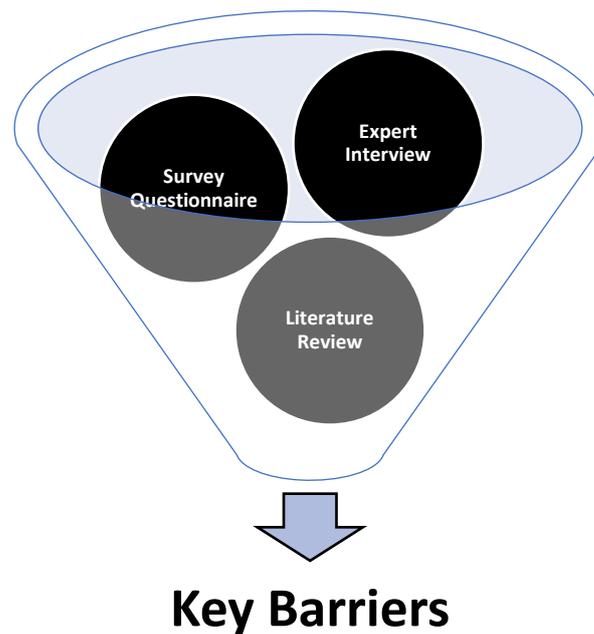


Figure 5.2: Identification process of the key barriers to achieving NZEB in Nigeria

Figure 5.2 illustrates the process by which the critical barriers to achieving NZEBs in Nigeria were determined based on the findings of the literature review, survey questionnaire, and expert interview. The critical barriers to achieving NZEB in Nigeria, as determined through a thorough review of existing literature and corroborated by data analysis findings, encompass technical/technological, institutional, economic/financial, and social/cultural factors. This multifaceted nature of barriers aligns with the findings of Abubakar et al. (2017), who emphasised the interconnectedness of challenges facing sustainable building practices in Nigeria.

Technical/Technological Barriers: The validation of findings from the literature review by experts during the interview has established a consensus that Nigeria faces a notable scarcity of skilled professionals possessing the necessary technical knowledge and expertise to design, construct, and maintain NZEBs effectively. This shortage has emerged as a key barrier in the country's NZEB implementation pursuit. The scarcity of skilled professionals for NZEB implementation identified in this study echoes findings by (Wong and Lee 2020; Othman and Hamzah 2021), who observed similar challenges in other emerging economies. Moreover, the reliance on imported building materials aligns with IFC's (2021) analysis of sustainable construction practices in Sub-Saharan Africa, highlighting the need for localised solutions and capacity building. It also aligns with observations by Akadiri *et al.* (2019) on the challenges of sustainable construction in Nigeria. According to the experts, it was further emphasised that the nation heavily depends on the importation of building materials, resulting in a limited supply of energy-efficient building materials and technologies. The expert

interview yielded replies indicating that a very critical challenge faced in attaining NZEB designation is the limited availability of data on the energy performance of buildings in Nigeria. The experts emphasised that the scarcity of data about energy performance is a significant challenge in accurately assessing the progress made towards attaining NZEB and formulating an effective strategy for enhancing energy efficiency in buildings. The limited availability of data on building energy performance, highlighted by experts in this study, corresponds with Okoye *et al.* (2021) assertion that lack of comprehensive energy data hinders effective policy-making and implementation in the Nigerian building sector.

Institutional Barriers: According to the findings of the expert interview, it has been determined that the institutional framework responsible for the implementation and enforcement of energy efficiency policies and regulations in Nigeria is lacking in strength. The weak institutional framework corroborates Adeniran *et al.*'s (2020) analysis of policy implementation challenges in Nigeria's energy sector. The study additionally indicates that the absence of well-defined policies and regulations to facilitate the implementation of energy-efficient measures poses a significant obstacle to Nigeria's widespread adoption of NZEB. The absence of well-defined policies specific to NZEBs aligns with Olaniyan *et al.*'s (2018) call for more targeted policy instruments to drive energy efficiency in buildings. Finally, the bureaucratic process in obtaining building permits and approval in Nigeria can be lengthy and complex, therefore discouraging and potentially dissuading building owners and developers from pursuing NZEBs. The institutional barriers identified in this study, particularly the weak regulatory framework, mirror challenges previously faced by Colombia and Costa Rica as observed by Garcia *et al.* (2023) in their analysis of NZEB implementation in the regions. This suggests that strengthening institutional capacity may be a common need across emerging economies pursuing NZEB goals.

Economical/Financial Barriers: The existing body of literature suggests that economic/financial factors pose significant barriers to attaining NZEBs in Nigeria. The literature review, supported by the findings from the survey questionnaire and expert interview, indicates that the substantial financial investment required to construct buildings to meet NZEB standards, which involve the use of energy-efficient materials and technologies, poses a notable challenge. This challenge is particularly pronounced without incentives and financial support from the government or other funding entities. Consequently, a dearth of enthusiasm is observed among most stakeholders, including building owners and developers, due to the formidable challenge of securing financial resources for energy-efficient building initiatives. The substantial financial investment required for NZEB construction, without adequate incentives or financial support, mirrors challenges identified by Nwoke *et al.* (2020) in their study of barriers to green building adoption in Nigeria. This finding underscores the need for

innovative financing mechanisms, as suggested by Onyenokporo and Danladi (2022) in their analysis of sustainable building finance in developing countries.

Social/Cultural Barriers: The study findings derived from the literature analysis and survey questionnaire have revealed Social/Cultural barriers as a highly significant barrier to attaining NZEB in Nigeria. Moreover, it was emphasised in the expert interview that the attitude and perception of stakeholders towards the notion of environmental sustainability are of significant concern. Most of these stakeholders exhibit an indifferent demeanour, despite repeated appeals for them to adopt a more sustainable strategy within the industry. The indifferent attitude of stakeholders towards environmental sustainability, despite repeated appeals, aligns with observations by Mbunwe *et al.* (2019) on the low level of environmental consciousness in Nigeria's construction industry. The cultural perception of energy as an inexhaustible resource, contributing to inefficient consumption patterns, corresponds with Akande's (2020) analysis of energy use behaviour in Nigerian households. Experts agree that the prevailing perspective on energy efficiency is influenced by a limited understanding of the advantages associated with NZEB, including potential cost savings and environmental benefits. Additionally, the absence of incentives and financial mechanisms from governmental and other funding entities contributes to the economic/financial barriers encountered in this regard. The expert interview findings indicate a cultural inclination to perceive energy as an inexhaustible resource, thereby potentially fostering inefficient energy consumption patterns.

The multifaceted nature of these barriers, spanning technical, institutional, economic, and social domains, underscores the complexity of the challenge as noted by World Bank (2023) in its study of NZEB implementation in emerging economies. While both survey respondents and interviewed experts identified lack of technical expertise as a significant barrier, the experts placed greater emphasis on the need for specialised training programs. This aligns with Ochedi's (2018) assertion that capacity building is crucial for successful NZEB implementation in emerging economies.

5.4 Key Drivers of NZEB in Nigeria

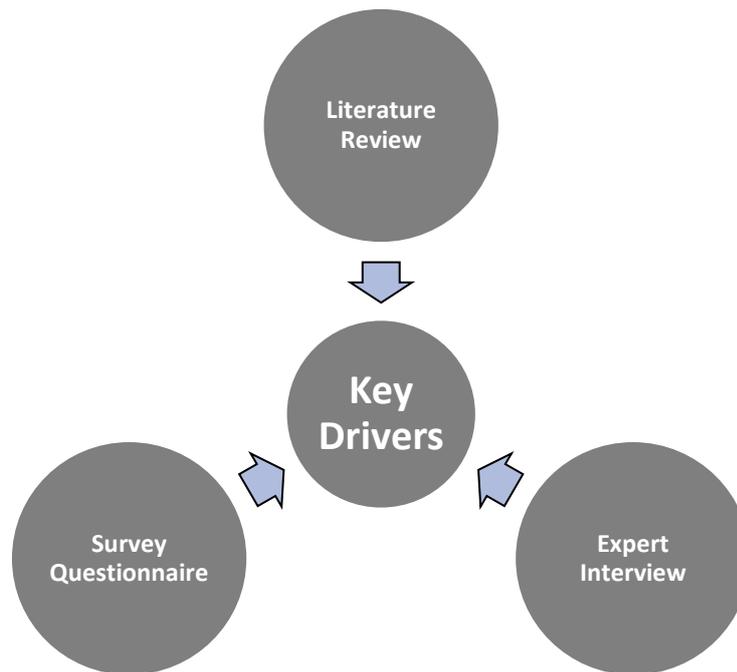


Figure 5.3: Identification process of key drivers of NZEB in Nigeria

Figure 5.3 illustrates the process by which the key drivers in the study were identified based on the literature review outcomes, survey questionnaire, and expert interview.

Findings from the literature review, survey questionnaire, and expert interview exposed key drivers of NZEBs in Nigeria. The drivers are policy development and implementation, government incentives, awareness creation, research funding, green investment, training of building professionals, building energy efficiency code/energy standards, and integrating green building courses in higher education curricula. These findings are consistent with Nwofe's (2019) comprehensive review of strategies for promoting sustainable buildings in developing countries.

The case study review findings demonstrate the successful transformation of Colombia's green building market to NZEB status within four years. This accomplishment was made possible through the establishment of public-private partnerships, wherein the Colombian government collaborated with the World's Bank IFC to create a supportive policy and regulatory environment, develop financial mechanisms for homeowners and developers, train building professionals on the use of EDGE software, and partner with universities to introduce a course that trains future building professionals. When queried about the case study, several experts emphasised the significant role played by the partnership between the Colombian government and the IFC in driving the country's remarkable progress towards decarbonisation. They also said the Nigerian government may draw valuable lessons from this experience. The findings of the survey questionnaire are consistent with these drivers, as a significant number of respondents identified policy creation and implementation, integration of green

building courses in higher education curricula, government incentives, awareness creation, research funding, green investment, compliance with building energy efficiency code/energy standard, and training programmes for building professionals as the key drivers driving the adoption of NZEBs in Nigeria. The emphasis on public-private partnerships in Colombia's success story supports Amasuomo et al.'s (2017) assertion that collaboration between government and private sector is crucial for driving sustainable building initiatives in Nigeria.

The findings from the expert interview validated the findings from the survey questionnaire. The interview findings indicate that the issue of achieving NZEB in Nigeria can be addressed through various measures such as increased investment in research and development, incentives for building owners and developers such as tax incentives, low-interest loans, and grants, capacity building for stakeholders in the building industry to increase knowledge and expertise in energy-efficient projects, public awareness campaigns to address the cultural gap, engaging with local communities to promote energy-efficient practices, development and deployment of innovative technology, having lack of data available on energy performance of buildings lack of data available on energy performance of buildings, making data on energy performance of building available, and finally encouraging the local production of green building materials. The survey and interview findings on key drivers corroborate Emetero *et al.*'s (2020) study on factors influencing green building adoption in Nigeria, which similarly highlighted the importance of policy measures, education, and financial incentives. The need for increased investment in research and development, as identified by experts, aligns with Oyedepo's (2019) call for more robust research infrastructure to support sustainable energy initiatives in Nigeria. The emphasis on public awareness campaigns to address cultural gaps corresponds with Olanipekun et al.'s (2017) findings on the role of social factors in sustainable construction practices. Finally, the need for encouraging local production of green building materials echoes recommendations by Dalibi et al. (2020) for developing indigenous sustainable building materials to reduce reliance on imports and lower costs.

While this study identified key drivers for NZEB implementation in Nigeria, further research is needed to quantify the potential impact of each driver. As suggested by Thompson (2022), understanding the relative importance of different factors can help prioritise interventions and allocate resources more effectively.

5.5 Proposed Strategic Roadmap

This section explores the recommended strategic pathway for achieving NZEB in Nigeria by the year 2060, based on the synthesis of the research findings. The nature of the roadmap is timebound and encompasses the energy-efficiency measures, barriers, and drivers identified in this study, and lessons

from Colombia and Costa Rica. The roadmap presents a step-by-step guide that outlines a sequential framework encompassing policy interventions, financial mechanisms, low-carbon measures, technological advancements (such as energy-efficient building materials and renewable energy technologies), partnerships, and capacity building. These strategies can be implemented over different time horizons, including short-term, mid-term, and long-term periods. Below is the proposed roadmap.

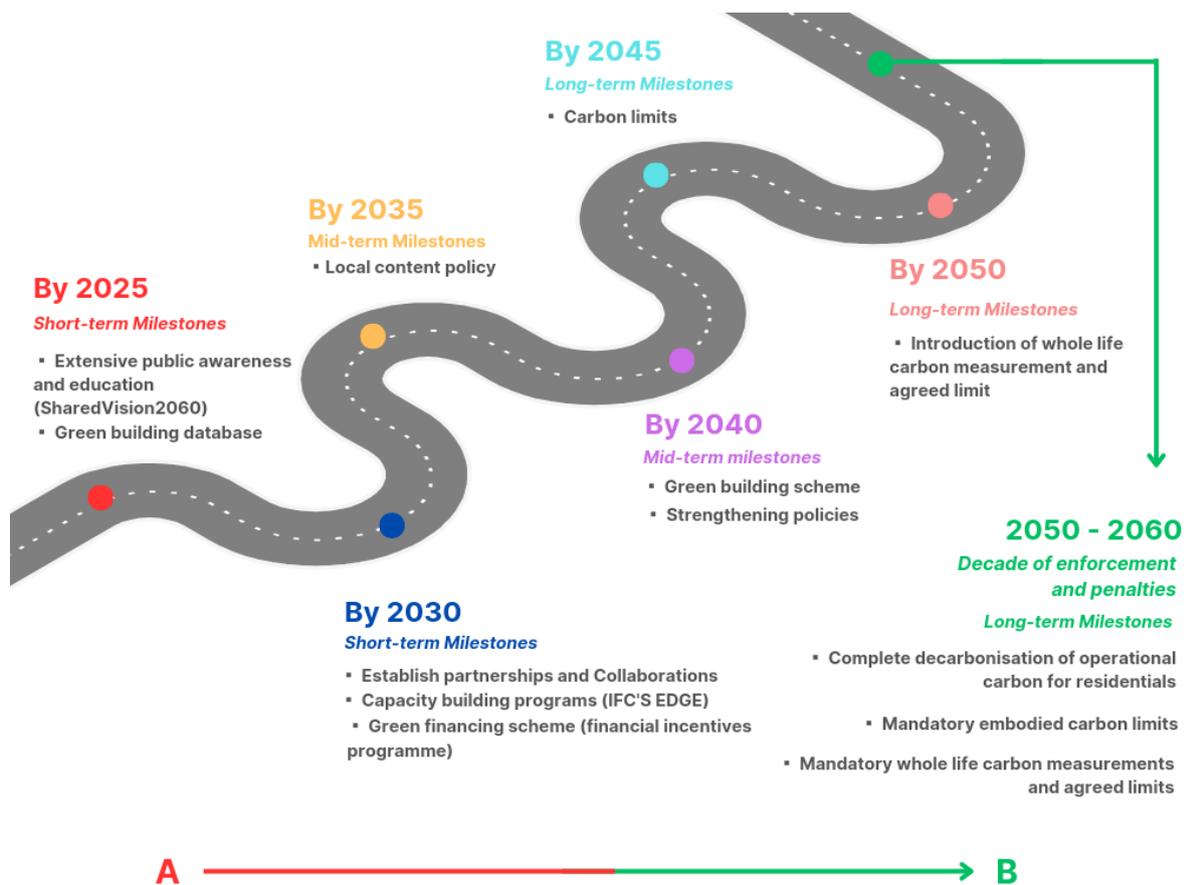


Figure 5.4: Proposed Strategic Roadmap

Figure 5.4 illustrates the proposed strategic roadmap to NZEB by 2060

Table 20: Detailed Proposed Strategic Roadmap

Timeline	Action Plan
By 2025 <i>Short-term Milestones</i>	Extensive Public Awareness and Education (SharedVision2060): All stakeholders – government, professionals, building owners and developers, students as well as the members of the public needs to buy into a clear and precise picture of where Nigeria should be by 2060 and the steps needed to get there. This can be achieved through extensive public awareness and education. By 2025, the Nigerian government should launch a public awareness campaign and engage with local communities to educate

	<p>the public on the many benefits of NZEBs and encourage the adoption of energy-efficient practices in buildings. This awareness campaign should target specifically, industry professionals, building owners and developers. This will address the existing cultural gap.</p> <p>Green Building Data Base: By the end of the year 2025, a data base which contains information and data on sustainable and environmentally friendly building practices, materials, and certifications should be developed. This database should serve as valuable resources for architects, builders, researchers, and anyone interested in the construction of new-builds or retrofitting buildings with focus on sustainability and environmental impact reduction.</p>
<p>By 2030 <i>Short-term Milestones</i></p>	<p>Establish Partnerships and Collaborations: Although few partnerships and collaborations have been identified in this study, by 2030, the government should seek to establish more relevant partnerships with international organisations, and the private sector and further strengthen these ties to support the development and implementation of NZEBs in Nigeria. Most importantly, the government should partner with countries that have an advanced NZEB practice, specifically countries in Africa and emerging economies. This would see the Green Building Council of Nigeria (GBCN) and the professional bodies in the building sector play a key role. This will expediate action towards decarbonisation and reduce the pressure on the government.</p> <p>Capacity Building Programs (IFC's EDGE): A more developed capacity building program on energy-efficient building practices that builds on the existing programs should be developed by 2030 to enhance the extent of building professionals trained annually. Specifically, building professionals should be trained on the use of EDGE software as well as becoming a certified EDGE Expert. This would significantly bridge the skill gap.</p> <p>Green Financing Scheme (Financial Incentives programme): By 2030, the Nigerian government should develop a green finance scheme that gives building owners and developers who adopts NZEB, access to low-interest loans, tax credits, and grants. This will encourage and attract more people into adopting NZEB practices.</p>
<p>By 2035 <i>Mid-term Milestones</i></p>	<p>Local Content Policy: The government should establish a local content policy for NZEBs which will support the development of local skills and capabilities. Furthermore, a significant investment should be made towards local businesses that are developing energy-efficient materials and alternative energy technologies by 2045. This will reduce the reliance on imports and reduced the potential cost of NZEB.</p>
<p>By 2040</p>	<p>Green Building Scheme: By 2045, the Nigerian government should develop a scheme</p>

<i>Mid-term Milestones</i>	<p>which will be aimed at producing more green building professionals and green building jobs. As part of this scheme, green building courses should be integrated into higher education curriculum for students in the building industry.</p> <p>Strengthening Policies: By the year 2035, all regulations, standards, and incentives for the effective implementation of NZEB practices in new builds should be strengthened.</p>
By 2045 <i>Long-term Milestones</i>	<p>Carbon Limits: By 2045, building regulation limits on operational carbon and embodied carbon for residential buildings should be introduced. This limit should get stricter overtime to encourage significant emissions reductions.</p>
By 2050 <i>Long-term Milestones</i>	<p>Introduction of Whole Life Carbon measurement and agreed limit: This should be achieved by the start of the last decade. This should be periodically reviewed.</p>
2050 -2060 (Decade of Enforcement and Penalties) <i>Long-term Milestones</i>	<p>Complete decarbonisation of operational carbon for residential: All new build residential will be completely decarbonised at the turn of the decade.</p> <p>Mandatory embodied carbon limits: The agreed upon operational carbon limit for residential should be enforced at the turn of the decade – 2050.</p> <p>Mandatory Whole life carbon measurements and agreed limits: WLC measurement should be mandatory for all residential, and the agreed limit / threshold should be enforced at the turn of the decade – 2050.</p>

It is imperative to acknowledge that the implementation of monitoring and evaluation mechanisms is crucial to effectively monitor the advancements made in achieving NZEB at various stages of the roadmap. Additionally, it is imperative to continuously update the roadmap to maintain its relevance and guarantee that it remains on track to accomplish the target set for the year 2060.

5.6 Validation of the Proposed Strategic Roadmap

The feasibility and adaptability of the strategic roadmap was validated through a focus group discussion involving key stakeholders such as GIZ, the Federal Ministry of Works, the Federal Ministry of Housing, NETP, the association of Nigeria's built environment professional bodies, leading research academics, contractors and consultants in the residential sector. Relevant data supporting the development of the strategic roadmap to NZEB was presented to the 9 participants, who were briefed about the research work's scope and relevance. The researcher walked through the milestone stages of the roadmap and invited participants to share their views, feedback, and comments. Their feedback was synthesised and analysed using thematic analysis technique with the aid of a software

synthesiser. The feedback from the experts provided valuable insights for refining and strengthening the roadmap. The key points from the expert validation are summarized below:

Timeframe and Continuity of Actions: The experts emphasised that the roadmap's timeline for awareness and training is too short. They recommended extending the initial public awareness and education phase from 2025 to 2028. Moreover, they stressed that these efforts should be continuous processes that overlap with subsequent milestones rather than being confined to the initial years.

Green Building Database: The experts suggested expanding the proposed Green Building Database to include case studies, best building practices, and a directory of certified energy-efficient and green building materials and technologies. They also recommended including guidelines and standards for energy efficiency and green building certifications to help professionals adhere to global and national sustainability benchmarks.

Capacity Building Programs: The experts emphasized the importance of including the BEEC as the benchmark for EE building design practices in Nigeria, in addition to international certifications like IFC's EDGE. They also recommended establishing regional training centres equipped with the latest technology and resources to facilitate hands-on learning and practical experience.

Partnerships and Collaborations: The experts suggested expanding partnerships to include academic institutions for research and development, as well as technology companies for innovation in energy-efficient and green building materials and techniques.

Economic Context and Financing: While acknowledging the current economic challenges, the experts recommended including financial incentives for retrofitting existing buildings to meet NZEB standards. They also suggested collaborating with financial institutions to create green bonds and other innovative financing mechanisms, along with providing financial literacy and advisory services to potential beneficiaries.

Local Content Policy and Skills Development: The experts provided detailed suggestions for the local content policy, including mandating the use of locally produced materials and services, establishing research and development grants for local startups, and creating partnerships between local manufacturers and international firms to facilitate technology transfer.

Green Building Scheme and Education: The experts recommended that the green building scheme should include continuous professional development programs, certifications, and apprenticeships. They also suggested partnerships with international green building certification bodies and universities to enhance the quality and relevance of educational programs.

Policy and Regulatory Framework: The experts emphasised the need for regular reviews and updates of building regulations to keep pace with technological advancements and evolving best practices. They also stressed the importance of implementing rigorous compliance and enforcement mechanisms.

Carbon Limits and Whole Life Carbon (WLC) Measurements: The experts supported the introduction of carbon limits and WLC measurements, suggesting that making these mandatory will incentivize builders and developers to adopt more sustainable practices and materials throughout a building's life cycle.

Realistic Implementation Considering Local Context: The experts maintained their emphasis on aligning the roadmap with Nigeria's economic realities and development priorities.

Continuous Adaptation and Review: The experts highlighted the need for periodic reviews and updates of the roadmap, particularly for long-term goals and standards.

The expert validation process has provided insights for refining the proposed strategic roadmap for NZEBs in Nigeria. The feedback emphasizes the need for a more flexible, economically sensitive, and integrated approach that builds on existing initiatives and stakeholders. The experts have provided specific recommendations for each stage of the roadmap, from expanding the initial awareness and education phase to implementing stringent carbon limits and whole life carbon measurements in the final stages.

5.7 Chapter Summary

This chapter synthesised the study's findings, offering insights into the current state of NZEBs in Nigeria. The current state of NZEBs in Nigeria was exposed, highlighting key barriers, including technical, institutional, economic, and social factors, hindering NZEB adoption. Additionally, it highlights crucial drivers such as policy development, government incentives, awareness campaigns, training, and partnerships. Finally, it presented the proposed NZEB roadmap with short, mid, and long-term actions to achieve new-build residential NZEB in Nigeria by 2060, and the validation of the roadmap by green building experts. The following chapter will summarise the content of this study and highlight its contribution to knowledge. The chapter will also discuss how this body of work may be expanded through further research.

CHAPTER 6: CONCLUSION, RECOMMENDATION, AND FUTURE WORKS

6.1 Chapter Introduction

This chapter provides a concise overview of the research and discusses how the study's aim, objectives, and research questions were effectively addressed. It underscores the study's contribution to the existing body of knowledge, proposes a recommendation for policymakers, delineates potential areas for future research, and culminates with a concluding remark encompassing the entirety of the study.

6.2 Summary

The study's aim was to develop a strategic roadmap for achieving Net Zero Energy Buildings in Nigeria (see section 1.7). The research successfully developed a strategic roadmap for implementing NZEBs in Nigeria by 2060, based on comprehensive literature review, surveys, and expert interviews. The study identified key drivers, barriers, and strategies for large-scale NZEB adoption, considering Nigeria's unique context. The proposed roadmap outlines short, medium, and long-term strategies integrating policy, regulation, investment, and partnerships. Its implementation could significantly impact sustainable construction in Nigeria, reduce carbon emissions, and contribute to achieving relevant UN Sustainable Development Goals. The study addresses gaps in NZEB literature for emerging economies and provides practical guidance for stakeholders. The roadmap is designed to be adaptable, considering local economic realities and capacity-building needs. The validation process emphasised the importance of multi-stakeholder collaboration and a phased approach balancing ambition with practicality. Overall, this research contributes both theoretically and practically to advancing NZEB implementation in Nigeria and potentially other emerging economies, promoting sustainable development and climate action

The objectives developed to achieve this aim and how they were addressed are discussed below (see section 1.7).

- 1. To review relevant literature on the concept and status quo of net-zero energy buildings in Nigeria in order to gain existing knowledge and identify the gaps in knowledge.**

The study conducted a literature review on NZEBs within three categories to address this objective. The first category was a global review to understand its concept and the progress made towards achieving the ambitious Paris Agreement. The second category was a review on emerging economies to determine the status of NZEB in emerging economies and gain insight as to how Nigeria compares with other emerging economies towards decarbonisation.

The third category was a review within the Nigerian context to ascertain the status quo of net-zero energy buildings in Nigeria.

The literature review revealed that while the concept of NZEBs is well-established globally, there is a significant gap in knowledge regarding the implementation of NZEBs in emerging economies, particularly in Nigeria. The review highlighted the limited research and practical applications of NZEBs in the Nigerian context, underscoring the need for focused efforts to address this gap.

2. To identify the key barriers that hinder the transition to Net-Zero Energy Buildings in Nigeria using a survey questionnaire and expert interview.

It was necessary to identify the key barriers that hinders the adoption of NZEBs in Nigeria and how these barriers are crucial to achieving NZEB. This objective was achieved through a thorough review of literature to expose these key barriers, and a follow-up with a survey questionnaire and an expert interview to understand the importance of these barriers towards achieving NZEBs in Nigeria.

The survey questionnaire and expert interviews identified several key barriers hindering the transition to NZEBs in Nigeria. These barriers include lack of awareness and knowledge, high initial costs, lack of regulatory frameworks and policies, limited access to financing, and inadequate technical expertise. Additionally, the findings revealed that overcoming these barriers is crucial for achieving the successful implementation of NZEBs in the country.

3. To identify the key drivers of Net-Zero Energy Buildings in Nigeria using survey questionnaire, expert interview, and case study reviews.

After identifying the key barriers to achieving NZEBs in Nigeria, to develop the strategic roadmap this research aimed to achieve, it was essential to identify the key drivers of NZEB. This objective was achieved through thorough review of the literature, to expose these key drivers, and a follow-up with a survey questionnaire and an expert interview to understand the factors that could drive NZEB practice in Nigeria.

The research identified several key drivers that can facilitate the adoption of NZEBs in Nigeria. These drivers include government policies and incentives, increased awareness and education, access to financing and investment opportunities, availability of skilled professionals and technical expertise, and the development of local technologies and materials. Case studies of successful NZEB projects in other emerging economies provided valuable insights into effective strategies and best practices.

4. To analyse the collected data employing descriptive and inferential statistics for quantitative data and thematic analysis for qualitative data, to ensure a comprehensive understanding of

the barriers, drivers, and strategic pathways towards achieving Net-Zero Energy Buildings in Nigeria.

For the quantitative data collected through the survey questionnaire, descriptive statistics were used to provide an overview of the responses, including measures of central tendency and dispersion. Inferential statistics, such as correlation analysis and regression analysis, were applied to identify significant relationships between variables and to determine the relative importance of various factors influencing the adoption of NZEBs in Nigeria. For the qualitative data gathered from expert interviews, thematic analysis was conducted to identify recurring themes, patterns, and insights. This approach allowed for a deeper understanding of the complex issues surrounding NZEBs in Nigeria, capturing nuanced perspectives that might not be evident in quantitative data alone. Quantitative analysis revealed statistically significant correlations between certain barriers and drivers, highlighting the interconnected nature of challenges and opportunities in implementing NZEBs. Inferential statistics helped prioritise the most critical barriers and drivers, providing a data-driven basis for developing targeted strategies in the roadmap. Thematic analysis of qualitative data uncovered additional context-specific factors not initially captured in the literature review, enriching the understanding of the Nigerian NZEB landscape. The mixed-methods approach allowed for triangulation of data, enhancing the reliability and validity of the findings. The analysis provided a comprehensive understanding of the barriers, drivers, and potential strategic pathways, which directly informed the development of the strategic roadmap. The combination of quantitative and qualitative analyses offered both breadth and depth in understanding the complexities of achieving NZEBs in Nigeria, ensuring that the proposed roadmap is both data-driven and contextually relevant. This objective was crucial in bridging the gap between raw data collection and the development of an informed, evidence-based strategic roadmap for achieving Net-Zero Energy Buildings in Nigeria by 2060.

5. To develop strategic roadmap towards achieving Net-zero Energy in residential buildings in Nigeria by 2060.

This objective was achieved in Chapter 5 (Discussion and Proposal) where the proposed strategic roadmap was developed following the findings from synthesising the literature reviews including a case study review, survey questionnaire and expert interview. Based on the findings from the literature review, survey questionnaires, and expert interviews, a strategic roadmap was developed to guide the transition toward achieving net-zero energy in residential buildings in Nigeria by 2060. The roadmap outlines specific short-term, medium-term, and long-term strategies, including policy interventions, regulatory frameworks,

investment opportunities, capacity building, and technology development. The roadmap also incorporates timelines, milestones, and the involvement of various stakeholders to ensure effective implementation and monitoring.

Table 21: Addressing the research question.

Research Question	How the research questions was addressed in the study.
What are the key barriers to achieving NZEBs in Nigeria?	The key barriers to achieving NZEBs in Nigeria were identified within the literature review and the responses from the expert interview.
What are the key drivers of NZEBs in Nigeria?	The key drivers of NZEBs in Nigeria were identified within the literature review and the responses from the expert interview.
How can a strategic roadmap be developed to guide the transition towards Net-Zero Energy in residential new buildings in Nigeria by 2060?	The strategic roadmap was developed in chapter 5 (Discussion and Proposal) after synthesising the findings from the literature review including case study reviews, survey questionnaire, and expert interview.

Table 21 depicts how the research questions was addressed in the study.

6.3 Contribution to Knowledge

The primary contribution of this Ph.D. research is the development of a strategic roadmap for achieving net-zero energy in residential new buildings in Nigeria by 2060. The proposed roadmap serves as a guideline for policymakers and other stakeholders involved in the building sector. This proposed roadmap outlines a step-by-step action plan that integrates multiple drivers identified from the study, to achieve the long-term goal. The specific contribution of this study to knowledge has been categorised under theory and practice.

Theoretical Contribution

This research made significant theoretical contributions by addressing the research gaps contributes to the broader theoretical discourse on sustainable development and climate action.

- **Research Gaps:** Very little has been done on the issue of NZEBs in the context of emerging markets as the literature review exposed this gap (see section 1.5). Furthermore, little has been done at a national level regarding developing a strategic roadmap for Nigeria. By adequately addressing the issue, context, and level of analysis gap, this research exposes the unique barriers and drivers relevant to achieving NZEB in the region therefore making a significant contribution to knowledge.

- **Sustainable Development and Climate Change:** There is a call to action on climate change by the UN convention. This thesis has contributed significantly to the global discourse on sustainable development and climate action by addressing the SDGs 7 (Affordable and Clean Energy), 11 (Sustainable Cities and Communities), and 13 (Climate Action).

Practical Contribution

This research offers significant practical contributions by providing a comprehensive and actionable roadmap for achieving NZEBs in the residential sector in Nigeria. The key practical contributions include:

- **Strategic Roadmap:** A major contribution of this study is the development of a strategic roadmap for achieving NZEBs in Nigeria by 2060. This roadmap serves as a guide and plan of action that outlines the necessary steps, policies, regulatory frameworks, and interventions to be implemented by policymakers, industry stakeholders, and other relevant actors for the country to achieve NZEB status by year 2060 according to the country's Paris Agreement. Other emerging economies can also adopt the findings from this study to help guide their transition to NZEB.
- **Evidence-Based Policymaking:** Findings from this study revealed limited data on NZEBs in Nigeria. Therefore, this thesis contributes to knowledge by providing relevant data on NZEBs in Nigeria and evidence to inform the formulation and implementation of effective policies relevant to NZEBs. Furthermore, by conducting an in-depth examination of social, economic, technical, and policy-related factors, the study contributes to a better understanding of the specific obstacles that need to be overcome to drive the transition to Net-Zero Energy.
- **Knowledge Transfer and Capacity Building:** The study's findings can be adopted by relevant bodies for knowledge transfer and capacity building initiatives, enabling industry professionals and stakeholders to acquire the necessary knowledge and skills for the scalable adoption of NZEBs in Nigeria.
- **Replicability:** While the roadmap is specific to Nigeria, the research methodology and findings can serve as a reference for other emerging economies seeking to develop similar strategies for achieving NZEBs, thereby contributing to global efforts towards sustainable development and climate action.

Overall, the implementation of the proposed roadmap can catalyse the scalable adoption of net-zero energy residential buildings in Nigeria, thereby reducing the country's carbon footprint and supporting its sustainable development goals.

6.4 Research limitation

The research has drawn on several resources to accomplish its aim. However, it is important to acknowledge its limitation. The research limitation is discussed below.

- The novelty of NZEB proved to be a limitation. There is a limited study on NZEB in the Nigerian context (the more reason why this research contributed towards addressing this knowledge gap). As this has been less discussed in the literature, existing literature on NZEB in the Nigerian context was challenging to come by. Data on NZEBs in Nigeria is limited due to availability, quality, and reliability. However, through intensive research, and robust data collection through survey questionnaires distributed to professionals in the field and most importantly expert interviews from NZEB experts, this limitation was addressed.

It is important to note that despite the research limitations mentioned above, the aim of this study was achieved as these limitations only serve as pointers to areas for further research.

6.5 Recommendations

Following the findings from this study, the researcher has identified significant recommendations specific to policymakers and other stakeholders. The recommendations are categorised below.

Stakeholder Recommendations

Government and Policymakers	Building Professionals	Homeowners / Clients
<p>1. Enforcement of standards and codes Enforce energy efficiency standards and building codes specifically designed for Nigeria's climate. This enforcement should be carried out in accordance with the timeline of the study's proposed strategic roadmap.</p> <p>2. Incentives Provide financial incentives, technical support, tax credits, and subsidies for residential builders and homeowners who incorporate renewable energy sources in their building projects.</p> <p>3. Capacity Building Invest in training programs that equips building inspectors to enforce energy efficiency standards.</p> <p>4. Strengthen Partnerships Strengthen existing partnerships such as the partnership with IFC. Similar partnerships have proven to be a critical driver in transforming the building sector in similar regions.</p> <p>5. Transparent Data Gathering Establish a system that collects and shares data on energy performance in residential buildings transparently. This will enable informed policy decisions and continuous improvement.</p>	<p>1. Training and Certification / CPD Building professionals should continuously undergo training and certification programs such as the IFC'S EDGE (which is simple to use and does not require any expertise), to enhance their knowledge of energy-efficient buildings.</p> <p>2. Energy Modelling Incorporate energy modelling and simulation tools in the design phase to optimize building energy performance before construction begins.</p> <p>3. Advocacy Advocate for net-zero energy policies and incentives at the local and national levels to support broader adoption within communities.</p>	<p>1. Awareness and Education Actively participate in educational programs to understand the benefits of net-zero energy living and environmental sustainability practices.</p> <p>2. Financing Options Explore available financing options, such as green mortgages or low-interest loans, to invest in the procurement of new homes.</p> <p>3. Energy Monitoring Homeowners should install energy monitoring systems in homes to track and optimize energy use. This will support Homeowners in making informed decision.</p>
<p style="text-align: center;">Researchers and Academia</p> <p>1. Interdisciplinary Research Encourage interdisciplinary collaboration among researchers from various fields. This will address the multifaceted challenges of net-zero energy buildings.</p> <p>2. Data Collection and Analysis Conduct extensive research on local climate conditions, energy Consumption patterns, and socio-economic factors to develop context-specific solutions.</p> <p>3. Knowledge Dissemination Share research findings and best practices through workshops, conferences, and publications to facilitate knowledge transfer within the industry</p>		

Figure 6.1: Study recommendation

Figure 6.1 delineates the study's recommendations for the key stakeholders.

6.6 Future Research

The research has established a strong base of knowledge for NZEBs in Nigeria. In the process, areas for potential future research were teased out. The following are areas potential future research can build on.

- Integration of Smart Technologies:** Future research can focus on integrating smart technologies in residential buildings to optimise energy consumption, enhance grid integration and improve overall energy management. This can involve investigating the potential of Internet of Things (IoT) devices, building automation systems, and advanced

energy management platforms in facilitating the transition to Net-Zero Energy and exploring the challenges and opportunities associated with their implementation.

- **Long-Term Monitoring and Adaption:** As the strategic roadmap spans several decades, future research can emphasise the importance of long-term monitoring, evaluation, and adaptation. This can involve developing robust monitoring frameworks, tracking progress towards Net-Zero Energy targets, assessing the evolving policy and technology landscape, and identifying opportunities for recalibration and adjustment of the roadmap to align with emerging trends.
- **Lifecycle Analysis of Buildings and Circular Economy in Nigeria:** this is an interesting area that this study identified as an area for further studies. Lifecycle Analysis in buildings involves analysing buildings to assess their environmental impact from construction to demolition. Future works on this can include the evaluation of embodied energy of building materials (as most works have focused on operational energy), reduction of construction waste and opportunities for integrating circular economy principles in the Nigerian building sector.
- **NZEB Technological Interventions:** Future research to address NZEB technological interventions and its applicability in the Nigerian context is essential. Some of the areas that can be explored within this topic include smart technologies and energy management systems, energy efficient building systems, and building integrated renewable energy systems.
- **NZEB Retrofit:** With the overwhelming number of conventional buildings in Nigeria with high energy consumption, future research that investigates retrofitting of existing building stocks to NZEB standard will be making a significant contribution to knowledge. Some of the topics that can be explored include retrofit strategies and technologies, advanced energy modelling and simulation tools specific to NZEB retrofits.
- **Building Information Modelling:** BIM supports the design, construction, and operation of energy-efficient buildings through integrated workflows, virtual energy modelling, clash detection, and life cycle analysis. Study that investigates its application in NZEB projects in the Nigerian context will be an interesting area for future research.

The areas for future research can further enhance knowledge and contribute to the ongoing efforts in achieving NZEBs in Nigeria.

6.7 Conclusion and Closing Remarks.

The building industry is widely believed to be a major contributor to global GHG emission and consequently climate change worldwide. Emerging economies, specifically Nigeria has a crucial role to play in achieving the Paris Agreement of decarbonisation. This thesis achieved its aim of developing a

strategic roadmap for achieving Net-Zero Energy Residential New Buildings in Nigeria by 2060. By so doing, a significant contribution has been made towards the knowledge and understanding of NZEBs in the context of emerging economies. Ultimately, this thesis has contributed to the global discourse on sustainable development and climate action call by the UN by addressing the SDGs 7, 11, and 13. Furthermore, this roadmap potentially provides valuable guidance for policymakers, practitioners and other stakeholders involved in sustainable building practice. By implementing this strategic roadmap, Nigeria can become a leading NZEB country in Africa and by extension the world. While this roadmap was developed for Nigeria, it can be applicable in other context, most importantly, emerging economies.

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APPENDICES

Appendix 1 – Ethical Approval Form

Res 20. Projects involving questionnaires or interviews



RES 20

Projects involving Questionnaires or Interviews

Faculty of Science and Engineering Ethics Committee (FSEEC)

This form should be word processed and emailed by the Supervisor to the relevant School Ethics Committee Administrator:

Life Sciences Ethics Committee (Includes School of Sciences and School of Pharmacy) [REDACTED]
Mathematics and Computer Science – tbc
Architecture and the Built Environment – tbc
Engineering – tbc

No handwritten forms can be considered

- **ALL** sections of this form must be completed
- **No project may commence without authorisation from the appropriate School Ethics Committee**

<p>CATEGORY A PROJECTS:</p> <p>Participants are all over 18 and not considered to be "vulnerable". All data normally to be confidential and anonymised. Questions are not embarrassing, distressing or highly personal. Examples of questions might be to elicit opinions on policies, local environment or behaviour. Questions may require gathering anonymised data on sex, age category, ethnicity.</p> <p>Participants should be informed of the nature of the research project and documented informed consent must be obtained, where appropriate.</p> <p>A risk assessment should be carried out where appropriate.</p> <p>All questionnaires and interview questions, and the final written questionnaire, must be vetted and approved by the Supervisor before they can be distributed.</p> <p>Most projects are expected to be Category A.</p> <p>CATEGORY B PROJECTS:</p> <p>This category may involve the administering of questionnaires or interviews on sensitive issues, or request provision of sensitive personal data.</p> <p>Participants may be under 18 or considered to be "vulnerable".</p> <p>Participants are to be informed of the nature of the research project and documented informed consent form must be obtained, where appropriate.</p> <p><u>Undergraduates will not normally be permitted to carry out Category B projects.</u> Projects will also be considered Category B if they are not covered by School Safety Codes of Conduct.</p>

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Page 1 of 7

Res 20. Projects involving questionnaires or interviews

Section A: To be completed by Supervisor

<p>1. For taught degrees, all projects must be approved by the appropriate Project Validation Committee. N/A</p> <p>Name of project validation committee:</p> <p>Date approval granted:</p> <p>2. Has this project (or a very similar project) been previously approved by an FSE Ethics Committee?</p> <p>Yes <input type="checkbox"/></p> <p>No <input checked="" type="checkbox"/></p> <p>If Yes, please provide a reference and date for the project previously approved (for example, student name or Ethics Committee reference number).</p> <p>Reference:</p> <p>Date:</p> <p>3. Are there any substantial changes to the previously approved form? (For example, major changes to experimental design, types of samples.)</p> <p>Yes <input type="checkbox"/></p> <p>No <input checked="" type="checkbox"/></p> <p>If Yes, please detail the changes below.</p> <p>Changes:</p> <p>4. If you have any specific comments that you wish to raise with the FSEEC please detail these below (for example if you are submitting a group of very similar projects for review). No</p>

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Page 2 of 7

Section B: To be completed by the researcher

For taught degrees, to be completed by the student and checked by the supervisor

Student/Staff Member* name <i>*please delete as appropriate</i>	Chieloka Emmanuel
Student number and email address/ Staff Member email address* <i>*please delete as appropriate</i>	[REDACTED]
Degree title / Course / School* <i>*please delete as appropriate</i>	Sustainable Architecture
Full detailed title of Project	Towards Net-Zero Energy Buildings in Tropical Climate: A study of residential buildings in Lagos.
University Supervisor name, telephone ext. and email address <i>(where applicable)</i>	Dr Louis Gyoh [REDACTED]
Work-based Supervisor name, telephone ext. and email address <i>(where applicable)</i>	
Level of Research: <i>(e.g. BSc, MSc, PhD, staff)</i>	PhD

Do you consider your project to be:

Category A (tick box to right)	<input checked="" type="checkbox"/>	Category B (tick box to right)	<input type="checkbox"/>
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Please consult University of Wolverhampton Ethics Guidance on Ethical Categories (www.wlv.ac.uk/research/about-our-research/policies-and-ethics/ethics-guidance/ethical-categories/) in conjunction with the following questions to inform your assessment.

		YES	NO
Do any participants fall into any of the following special groups? If they do your research should be classed as Category B. Note that you may also need to obtain satisfactory DBS (formerly known as CRB) clearance (or equivalent for overseas students).	Children (under 18 years of age)*	<input type="checkbox"/>	<input checked="" type="checkbox"/>
	People with learning or communication difficulties	<input type="checkbox"/>	<input checked="" type="checkbox"/>
	Patients (including people with diagnosed psychological conditions)	<input type="checkbox"/>	<input checked="" type="checkbox"/>
	People in custody	<input type="checkbox"/>	<input checked="" type="checkbox"/>
	People engaged in illegal activities (e.g. drug-taking)	<input type="checkbox"/>	<input checked="" type="checkbox"/>

* If you will always be accompanied by a teacher throughout any practical work with school children you may decide that this is a low risk, Category A project

<p>1. Describe the key purpose of the research proposed. <i>1-2 paragraphs of rationale, aims, objectives, plus small number (1-3) of key references</i></p> <p>Climate change is a global crisis that requires urgent action. The rapid change to the climate due to anthropogenic activities has been well documented in literature. The goal is to keep the global emissions to 1.5 degrees to achieve a net zero emission globally by 2050 (WorldGBC, 2020). Buildings are major contributors to climate change and emits a significant proportion of greenhouse gases (GHG). Although several studies have been carried out in the area of energy efficiency in residential buildings, most studies tend to focus on temperate regions hence a gap in the context of hot humid tropical climate (Li et al., 2022). The energy hot spots by 2050 will be located along the tropics due to a surge in population in this region resulting in increased need for energy consumption (EIA, 2019). Therefore, a decarbonization strategy for buildings in tropical climate is imperative.</p> <p>This study aims to develop a strategy for the decarbonization of residential buildings in Tropical Climate.</p>
<p>2. Explain your sampling strategy: <i>e.g. how will you select participants? How will you distribute and collect questionnaires? Where will you interview participants? How will you record interview responses? How will you gain the participant's consent to take part in the study? Please consult University of Wolverhampton Ethics Guidance on Recruiting Research Participants (http://www.wlv.ac.uk/research/about-our-research/policies-and-ethics/ethics-guidance/recruiting-research-participants/) for advice.</i></p> <p>The stakeholders in the procurement of building in Nigeria constitute construction professionals. Therefore, the population in the study survey will be reflected by the Professional Standard Regulatory Bodies (PSRB) – Nigerian Institutes of Architects (NIA), Nigerian Institute of Builders (NIOB), Council for Regulation of Engineering in Nigeria (COREN), and Nigerian Institute of Quantity surveyors (NIQS). Against this background the sampling technique will be a stratified random sampling. The PSRB will represent the strata to ensure that construction professionals are represented in the study sample. Questionnaire will be distributed and collected via Google Form and consent will be sort from participants to take part in the 10-minute survey.</p>
<p>3a. Will you be issuing questionnaires? Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> If YES, please append completed questionnaire AND participant information sheet / consent form written in simple non-technical language. <i>If the questionnaire is not yet available please attach a list of indicative questions to help the Ethics Committee to determine if your questionnaire is likely to be ethical. Permission to carry out the survey will not be given until the final questionnaire and cover sheet have been approved.</i></p>
<p>3b. Will you be conducting interviews? Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> If YES, please append the list of interview questions AND participant information sheet / consent form written in simple non-technical language. <i>If the interview questions are not available please attach a list of indicative questions to help the Ethics Committee to determine if your interview questions are likely to be ethical. Permission to carry out the interviews will not be given until the interview questions and cover sheet / consent form have been approved.</i></p>

Res 20. Projects involving questionnaires or interviews

Please consult University of Wolverhampton Ethics Guidance on Information Sheets and Consent forms (<http://www.wlv.ac.uk/research/about-our-research/policies-and-ethics/ethics-guidance/recruiting-research-participants/information-sheets-and-consent-forms/>) for advice.

4. Check list for Participant Information Sheet and Consent Form

A. Will you describe the main research procedures to participants in advance, so that they are informed about what to expect? Yes No

B. Will you tell participants that their participation is voluntary? Yes No

C. Will you obtain written consent for participation? Yes No N/A

D. For self-completion questionnaires, will you tell participants that submission of an anonymous completed questionnaire implies consent to participate? Yes No

E. Will you tell participants that they may withdraw from the research at any time without giving a reason? Yes No

F. Will you give participants the option of omitting any questions they do not wish to answer? Yes No

G. Will you tell participants that their data will be treated with full confidentiality and that, if published, will be anonymous? Yes No

If you have ticked **No** to any of these questions, please give an explanation in the space below.

5. In your view, what are the ethical considerations involved which could affect any of the participants?
These may include issues of consent, anonymity, confidentiality or risk.

Consent, Anonymity and Confidentiality

6. Is there any realistic risk of any participants experiencing either physical or psychological distress or discomfort? Yes No
If YES, give details in the space below and state what you will tell participants to do if they should experience any problems (e.g. how you will minimise discomfort or who they can contact for help).

7A. Please state location(s) where project will be carried out.
If this is not at the University campus, include a name, address and telephone number and/or e-mail details for your on-site contact person and a contact phone number for yourself when you are working off-campus.

7B. Will any data be collected from outside the UK? Yes No
If YES, please provide further details

Survey questionnaire will be distributed electronically from the university campus

8. Do you need permission to work at your chosen study site? Yes No
If YES, please append evidence of permission
If NO, please explain why permission is not needed

Survey questionnaire will be distributed electronically therefore permission is not applicable

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Page 5 of 7

Res 20. Projects involving questionnaires or interviews

9. Briefly describe your health and safety arrangements.

Not Applicable

10. Please state who, besides yourself, will have access to the raw data or responses, and what measures will be adopted to maintain the confidentiality of the research participants and to comply with data protection requirements (e.g. whether the data / responses will be anonymised).
Please consult University of Wolverhampton Ethics Guidance on Data Handling and Security (www.wlv.ac.uk/research/about-our-research/policies-and-ethics/ethics-guidance/data-handling-and-security/) for further information.

The primary data collected will be available for access by the student and the supervisory team. All responses are anonymous, and participants will not be identifiable. All data will be stored electronically on university server, using the personal file store (PFS), which will be password protected and only accessible to the researcher and the supervisory team during the project. Data will remain on the secured-on university server after the project and discarded in line with University policy on data protection.

11. Data storage and security

a. Data are usually stored for a maximum of 5 years. However on occasion data may need to be retained for longer. Please indicate how long data will be stored.

i. For a period of up to 5 years

ii. For longer than 5 years (please explain why)

b. Storage of data / responses must be secure to ensure that access to them is appropriately restricted. Indicate below how the data acquired are to be stored.

All data will be stored electronically on university server, using the personal file store (PFS), which will be password protected and only accessible to the researcher and the supervisory team during the project.

Data will remain on the secured-on university server after the project and discarded in line with University policy on data protection.

I am familiar with the University of Wolverhampton guidelines for ethical practices in research www.wlv.ac.uk/research/about-our-research/policies-and-ethics/ethics-guidance/ and have used them in compiling my proposal. **My supervisor has checked the information in this form.**

Print name: ...Chieloka Emmanuel..... Date: 24-06-2022....
(Researcher)

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Page 6 of 7

Res 20. Projects involving questionnaires or interviews

I have checked the information contained in this form and I am satisfied it is appropriate for submission.

Print name.. Dr Louis Gyoh..... Date: 24-06-2022
(Supervisor)

Ensure you include (if appropriate)

- Questionnaire
- List of interview questions
- Participant Information Sheet
- Consent Form
- Letter of Permission to work at the study site

All forms must be **in electronic format** so they can be forwarded to the Ethics Committee members.

The **Supervisor** should email the completed form and supplementary forms to the appropriate School Ethics Committee Administrator. Feedback will be emailed to the Supervisor and Student. Students may not communicate directly with the Committee.

Appendix 2 - Ethical Approval Letter

← RE: Ethical ^_Approval^_ Application ...

Dear Student,

Your ethics form has received approval subjected to amendments to the Participant information sheet/Questionnaire Cover letter. This should include details of confidentiality.

You MUST ensure a copy of this email is included in an appendix to your final thesis, when submitted.

Please be advised that before any data collection is collated you must get any questionnaires and/or interview questions (if you are using these methods) signed off by your supervisor and ensure a copy of the signed research questions are included in the thesis.

The confidentiality and anonymity of all participants and data in the work specified must be maintained during collection, analysis, dissemination and subsequent storage and disposal in line with the Data Protection Act (2018). Please follow the Ethics guidance as stated in <https://www.wlv.ac.uk/research/research-policies-procedures--guidelines/ethics-guidance/>

Kind regards,

ABE Ethics Committee

Appendix 3 - Consent Form

Google Forms

I've invited you to fill in a form:

Net-Zero Energy Buildings in Emerging Markets: A study of residential buildings in Nigeria.

The study aims to develop a strategic roadmap to achieve Net-Zero Energy Buildings in Emerging Markets – a study of residential buildings in Nigeria.

This survey is part of a Ph.D. in Sustainable Architecture at the University of Wolverhampton.

Completion of the attached questionnaire will take approximately 5 minutes, and all questions can be answered by following the simple instructions. Completion of the questionnaire is completely voluntary. Data collected for the purpose of this study is in accordance with General Data Protection Regulation (GDPR) and in line with the Economic and Social Research Council (ESRC) guideline and principles. Your response will be used solely for the purpose of this study.

Should you choose to complete the questionnaire and return it, this will be considered as your consent to participate in the survey.

Thank you for taking time to consider this invitation and if you choose to participate in this research, I would like to extend my personal gratitude; your contribution is greatly appreciated.

Chieloka Emmanuel
[REDACTED]
[REDACTED]

[FILL OUT FORM](#)

Appendix 4 – Survey Questionnaire

← Survey Questionnaire

1. This section is related to background information about you and your organization/company.

1.1 Which of the following categories best describes your profession?

Architect

Builder

Green Building Consultant / Energy Expert

Engineer

Quantity Surveyor

Estate Surveyor and Valuer

Other: _____

1.2 Which of the following best describes the sector you work in?

Public Sector

Private Sector

Third Sector

1.3 In which of these categories does your years of experience in the industry fall under? *

< 5

6 – 10

11 – 15

16 – 20

> 20

2. This section is related to you or your organisation's experience with energy-efficient building project(s).

For your reference, this study defines Energy-Efficient building as a building with a significant reduction in the amount of energy required to maintain or improve energy services to buildings.

2.1 How familiar are you with Energy-Efficiency (EE)? *

- Very Familiar
- Moderately Familiar
- Slightly Familiar
- Not at all familiar

2.2 How many Energy-Efficient Building Project(s) have you or your organisation been involved in? *

- < 5
- 6 – 10
- 11 – 15
- > 20

2.3. To what extent have you used the below National Building Energy Efficiency Code (NBEEC) interventions in building project? *

(Please Indicate using the Likert scale where 0 = Not at all, 5 = Very Much)

	0	1	2
Reduction of overall Window to Wall Ratio or implementation of shading	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduction of installed lightning power density	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Minimum requirements for roof insulation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Minimum performance of air conditioning equipment specified	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Installation of non-inverter split units to be restricted	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2.4 To what extent have you adopted Energy-Efficient strategy for the below categories? *

(Please indicate using the Likert scale where 0 = Not at all, 5 = Very Much)

	0	1	2	3
New Builds	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Retrofitted	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2.5. To what extent have you used Energy-Efficient strategies in the below building types. *

(Please indicate using the Likert scale where 0 = Not at all, 5 = Very Much)

	0	1	2	3
Residential Buildings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Commercial Buildings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Institutional Buildings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mixed-Use Buildings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

3. This section is related to energy standards/Certifications.

For your reference, NBEEC = National Building Energy Efficiency Code, EDGE = Excellence in Design for Greater Efficiencies

3.1 How familiar are you with the following energy standards? *

(Please indicate using the Likert scale where 0 = Not at all familiar; 4 = Very Familiar)

	0	1	2	3
NBEEC	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Passivhaus	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
EDGE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

3.2 Which of the following 'energy' standard/certification do you or your organization adopt in Energy-Efficient projects?

- NBEEC
- Passivhaus
- EDGE
- None
- Other: _____

4. This section is related to the barriers and drivers of Net-Zero Energy Buildings (NZEB).

For your reference, this study defines NZEB as an energy-efficient building with Net-Zero Energy Consumption, therefore the total amount of energy used by the building on an annual basis is equal to the amount of renewable energy created onsite or offsite,

4.1 Rank these key barriers to achieving NZEB in Nigeria in their order of importance. *

(Please indicate using the Likert scale where 0 = Not Important; 5 = Extremely Important)

	0	1	2
Technical/Technological	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Institutional	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Economic/Financial	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Social/Cultural	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

4.2 Rank these key **technical/technological barriers** to achieving NZEB in Nigeria in their order of importance. *

(Please indicate using the Likert scale where 0 = Not Important; 5 = Extremely Important)

	0	1	2
Lack of skills & expertise	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Uneven dissemination/distribution of knowledge amongst all stakeholders	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Inaccessibility of NZEB materials and technologies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of training programmes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of green building courses in higher education	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

4.3 Rank these key **institutional barriers** *

to achieving NZEB in Nigeria in their order of importance.

(Please indicate using the Likert scale where 0 = Not Important; 5 = Extremely Important)

	0	1	2
Lack of political will for transition	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of national NZEB roadmap	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of NZEB policy/regulations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of government incentives	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of policy implementation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

4.4 Rank these key **economic/financial barriers** *

to achieving NZEB in Nigeria in their order of importance.

(Please indicate using the Likert scale where 0 = Not Important; 5 = Extremely Important)

	0	1	2
Long payback period	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Capital intensive/High upfront cost	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Low investments	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of government funding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Difficulty calculating cost savings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

4.5 Rank these key **social/cultural** ^{*}
barriers to achieving NZEB in Nigeria in
 their order of importance.

(Please indicate using the Likert scale where
 0 = Not Important; 5 = Extremely Important)

	0	1	2
Conservative society/mindset	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of public awareness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Low consumer appeal	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Home-owners lack of NZEB knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

4.6 Rank these key drivers of NZEB in ^{*}
 Nigeria in their order of importance.

(Please indicate using the Likert scale where
 0 = Not Important; 5 = Extremely Important)

	0	1	2
Policy Creation & Implementation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Government Incentives	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Awareness Creation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Research Funding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Green Investment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Training of Building Professionals	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Building Energy Efficiency Code/Energy Standard	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Integration of green building course in higher education curriculum	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

What recommendation(s) would you provide for achieving NZEB in Nigeria?

Appendix 5 – Expert Interview Guide

EXPERT INTERVIEW GUIDE

Introduction:

- Brief overview of the research study and its objectives
- Explanation of the purpose and importance of the expert interview
- Assurance of confidentiality and anonymity of responses

Background Information:

1. Can you tell me about your professional background and expertise in the field of green buildings and energy efficiency?

Body:

Barriers: 2. In your opinion, what are the key barriers preventing building construction professionals from being more involved in energy-efficient building (EEB) projects in Nigeria? 3. How does the lack of market demand for EEB projects affect the involvement of building professionals in such projects? 4. Do you think the lack of expertise and technical know-how among building professionals is a significant barrier to their involvement in EEB projects? 5. Is there an information gap among building professionals and clients regarding the benefits and access to EEB technologies and practices? 6. How do supply chain challenges related to sourcing EEB materials and technologies impact the involvement of building professionals in EEB projects? 7. What role do you think the lack of incentives (financial, technical support, tax breaks) plays in discouraging building professionals from participating in EEB projects?

Drivers - Creation of a Green Building Database: 8. How can a comprehensive green building database be developed and implemented in Nigeria? 9. What kind of data should be collected for such a database, and how can this data collection process be standardized? 10. What role can collaboration between the government and building professionals play in setting up a green building database? 11. How can public awareness campaigns help in the implementation and utilization of a green building database? 12. How can policies and regulations be integrated to facilitate the development and adoption of a green building database?

Strategic Roadmap: 13. What key components should be included in a strategic roadmap for achieving Net-Zero Energy Buildings (NZEBS) in Nigeria by 2060? 14. How can capacity building (training, workshops, curriculum integration) be integrated into the roadmap to develop a skilled workforce for

NZEBS? 15. What role should research and development focused on NZEB technologies and practices play in the strategic roadmap? 16. How can collaboration and partnerships between the government, industry, academia, and international organizations contribute to achieving NZEBs in Nigeria? 17. What strategies for public awareness campaigns should be included in the roadmap to educate the public about the benefits of NZEBs? 18. How can regulatory compliance mechanisms, including monitoring and enforcement of green building regulations, be addressed in the strategic roadmap?

Closing:

- Thank the expert for their time and valuable insights
- Invite them to add any additional comments or suggestions
- Explain the next steps in the research process

Appendix 6 – Expert Interview Questions

EXPERT INTERVIEW QUESTIONS

Background Information
1. Can you tell me about your professional background, and expertise?
Content
Barriers:
<ol style="list-style-type: none"> 1. In your opinion, what are the key barriers preventing building construction professionals from being more involved in energy-efficient building (EEB) projects in Nigeria? 2. How does the lack of market demand for EEB projects affect the involvement of building professionals in such projects? 3. Do you think the lack of expertise and technical know-how among building professionals is a significant barrier to their involvement in EEB projects? 4. Is there an information gap among building professionals and clients regarding the benefits and access to EEB technologies and practices? 5. How do supply chain challenges related to sourcing EEB materials and technologies impact the involvement of building professionals in EEB projects? 6. What role do you think the lack of incentives (financial, technical support, tax breaks) plays in discouraging building professionals from participating in EEB projects?
Drivers - Creation of a Green Building Database:
<ol style="list-style-type: none"> 1. How can a comprehensive green building database be developed and implemented in Nigeria? 2. What kind of data should be collected for such a database, and how can this data collection process be standardized? 3. What role can collaboration between the government and building professionals play in setting up a green building database? 4. How can public awareness campaigns help in the implementation and utilization of a green building database? 5. How can policies and regulations be integrated to facilitate the development and adoption of a green building database?
Strategic Roadmap:

-
- | |
|---|
| <ol style="list-style-type: none"> 1. What key components should be included in a strategic roadmap for achieving Net-Zero Energy Buildings (NZEBs) in Nigeria by 2060? 2. How can capacity building (training, workshops, curriculum integration) be integrated into the roadmap to develop a skilled workforce for NZEBs? 3. What role should research and development focused on NZEB technologies and practices play in the strategic roadmap? 4. How can collaboration and partnerships between the government, industry, academia, and international organizations contribute to achieving NZEBs in Nigeria? 5. What strategies for public awareness campaigns should be included in the roadmap to educate the public about the benefits of NZEBs? 6. How can regulatory compliance mechanisms, including monitoring and enforcement of green building regulations, be addressed in the strategic roadmap? |
|---|

Appendix 7 - Expert Interview Transcript

EXPERT INTERVIEW TRANSCRIPT

Interview 1: Conversation held via telephone.

Interviewer: Thank you for taking the time to hold this interview with me today. Before we dive into the main discussion, could you please tell me a bit about your professional background and expertise?

Respondent: Certainly. I have been working in the Nigerian construction industry for over 15 years, with a focus on sustainable and energy-efficient building practices. I have been involved in several green building projects, both residential and commercial, and have gained extensive knowledge and experience in this field. My expertise lies in energy-efficient design strategies, renewable energy integration, and the use of sustainable building materials.

Interviewer: That's excellent. Your insights will be invaluable for our research on developing a strategic roadmap towards achieving Net-Zero Energy Buildings in Nigeria. Let's begin by discussing some of the key barriers preventing wider adoption of energy-efficient building practices.

In your opinion, what are the major barriers that have limited the involvement of building construction professionals in energy-efficient building (EEB) projects in Nigeria?

Respondent: One of the primary barriers is the lack of market demand for such projects. Many clients in Nigeria still do not prioritize energy efficiency, often due to perceived higher upfront costs or lack of awareness about the long-term benefits. As a result, building professionals are left with little choice but to work on conventional projects, as there is simply not enough demand for energy-efficient buildings.

Interviewer: That's an interesting point. Do you think the lack of expertise and technical know-how among building professionals themselves also contributes to this limited involvement?

Respondent: Absolutely. Most building professionals in Nigeria are not sufficiently skilled or trained in the specific techniques and technologies required for energy-efficient construction. This lack of technical know-how presents a significant barrier, as professionals may feel ill-equipped to take on such projects effectively.

Interviewer: I see. And is there also an information gap, both among professionals and clients, regarding the benefits of energy-efficient buildings and how to access the related technologies and practices?

Respondent: Yes, there is certainly an information gap on both sides. While some building professionals have a basic understanding of energy-efficient buildings, they may not fully comprehend the long-term benefits, such as reduced operational costs and environmental impact. On the client side, there is a massive lack of awareness about the advantages of energy-efficient construction and how to access the necessary materials and technologies.

Interviewer: That's a valid point. Now, let's discuss supply chain challenges. How do difficulties in sourcing materials and technologies for energy-efficient projects impact the involvement of building professionals?

Respondent: Supply chain challenges pose a significant hurdle. In Nigeria, many of the materials and technologies required for energy-efficient construction are not readily available locally. A substantial portion has to be imported, which creates logistical and cost challenges for developers. This difficulty in accessing the necessary resources discourages developers from pursuing energy-efficient projects, thereby limiting the opportunities for building professionals to be involved.

Interviewer: I understand. And what about incentives or the lack thereof? How does that factor into the equation?

Respondent: The lack of incentives, both financial and in terms of technical support or tax breaks, is a major deterrent. The Nigerian government does not appear to prioritize energy-efficient building projects, making it challenging for developers to access incentives that could offset the higher upfront costs. Without such incentives, developers are often discouraged from pursuing these projects, which, in turn, limits the involvement of building professionals.

Interviewer: Those are excellent points. Now, let's shift our focus to the potential role of a green building database in accelerating the adoption of energy-efficient practices. How can such a database be developed and implemented effectively in Nigeria?

Respondent: To develop a comprehensive green building database, we would need to collect and standardize data on various aspects of newly constructed buildings, such as energy consumption, materials used, construction methods, and carbon emissions. This data collection process would lay the foundation for the database's implementation.

Moreover, collaboration between the government and building professionals is crucial. The government and industry stakeholders need to work together to establish the framework, guidelines, and protocols for the database.

Interviewer: What about public awareness? How can campaigns help in the implementation and utilization of this database?

Respondent: Public awareness campaigns would be essential. The general public needs to be educated about the importance and benefits of a green building database. Robust campaigns could not only increase understanding but also facilitate data gathering by encouraging participation and cooperation from building owners and occupants.

From a policy standpoint, the government should integrate the green building database into building codes and regulations. This would ensure that energy efficiency requirements and net-zero energy targets are directly linked to the data from the database, enabling effective implementation and monitoring.

Interviewer: Those are all excellent suggestions. Finally, let's discuss the strategic roadmap itself. What key components should be included to achieve Net-Zero Energy Buildings in Nigeria by 2060?

Respondent: Capacity building is going to be crucial. The roadmap should include provisions for comprehensive training and workshops for building professionals on various aspects of net-zero energy building design, construction, and maintenance. This could involve collaborations with educational institutions to integrate these concepts into curricula, ensuring that future professionals are well-prepared from the outset.

Additionally, the roadmap should emphasize investment in research and development focused specifically on net-zero energy building technologies and practices. This would drive innovation and progress in the field, allowing Nigeria to stay at the forefront of developments.

Furthermore, collaboration and partnerships between the government, industry, academia, and international organizations must be a key component of the roadmap. Such collaborations can facilitate knowledge sharing, capacity building, and a collective push towards decarbonization goals.

Public awareness campaigns are another essential element. The roadmap should outline strategies for nationwide campaigns to educate the public about the benefits of net-zero energy buildings. This would increase awareness, support, and demand for such projects.

Lastly, the roadmap should address regulatory compliance mechanisms. This could include establishing systems for monitoring and enforcing compliance with green building regulations, as well as penalties for non-compliance. Such measures would ensure accountability and drive progress towards the 2060 target.

Interviewer: Thank you, this has been an incredibly insightful discussion. Your expertise and insights will be invaluable in shaping our recommendations for a comprehensive strategic roadmap towards achieving Net-Zero Energy Buildings in Nigeria.

Respondent: You're most welcome. I'm glad I could contribute to this important research. Achieving net-zero energy buildings is a collective responsibility, and a well-designed roadmap that addresses the key barriers, leverages enabling factors, and fosters collaboration among all stakeholders is crucial for Nigeria to meet its decarbonization goals in the building sector.