



Kim Del Kaze

Transformative Governance and Community Renewable Energy
Adoption: Integrating Decentralized Solutions for Sustainable
Energy Transitions in Northern Nigeria.

Faculty of Engineering and Applied Sciences
Energy and Sustainability

PhD
Academic Year: 2021-2025

Supervisor: Prof. Nazmiye Balta-Ozkan
Associate Supervisor: Dr. Elisabeth Shrimpton
March 2025



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the degree of PhD

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- the thesis submitted has not been previously submitted to this university or any other.
- that all content, including primary and/or secondary data, is true to the best of my knowledge.
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Abstract

This thesis examines how decentralized governance and citizen participation can accelerate renewable energy (RE) adoption in Nigeria. Working within a Community Renewable Energy–Multi-Level Governance (CRE-MLG) framework, the research integrates a household survey (n=559) and semi-structured stakeholder interviews (n=15) to identify determinants of adoption and practical pathways for implementation. Quantitatively, a multinomial logit model estimated in STATA, interpreted via average marginal effects (AMEs) and robustness checks, shows that income, education, and awareness are the most consistent predictors of readiness to adopt, with occupation adding important nuance (civil service/NGO > informal sector). At 15–20% above baseline income, the probability of high commitment rises by 44% points, and by 52% points at >20%, while awareness alone increases commitment by nearly 15% points. Interaction terms reveal diminishing returns to generic awareness at higher incomes and education-sensitive effects, indicating that adoption does not follow a simple linear path. Qualitative findings indicate that adoption depends as much on credible, proximate institutions as on affordability or information. Fragmented mandates, slow approvals, and weak accountability blunt household willingness to act. The thesis operationalizes this governance gap through Renewable Energy Desk Officers (REDOs) embedded in the local government(s) to coordinate approvals, consumer protection, data flows, and targeted information campaigns. Overall, the results position Nigeria's energy transition as fundamentally governance-oriented; awareness converts to action where finance is accessible, information is trusted, and delivery is reliable. Policy recommendations include income-segmented finance (subsidies, micro-finance, Pay-As-You-Go), education-sensitive messaging, occupation-routed outreach, and regulatory coherence implemented through REDOs. Re-channelling substantial private spending on backup generation toward decentralized renewables, under credible local delivery, can advance national targets while improving equity and reliability.

Keywords: Multi-level governance; Community renewable energy; Citizen participation; Multinomial logit; Average marginal effects; Renewable Energy Desk Officers (REDOs); Nigeria

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List of Abbreviations

AME	Average Marginal Effects
CHP	Combined Heat and Power
COP	Conference of Parties
CR	Critical Realism
CRE	Community Renewable Energy
DRE	Decentralized Renewable Energy
ETP	Energy transition Plan (Nigeria)
FiT	Feed-in-Tariff
FDI	Foreign Direct Investment
FG	Federal Government
GHG	Green House Gas Emissions
GW	Gigawatts
HRES	Hybrid Renewable Energy Systems
IEA	International Energy Agency
IIA	Independence of Irrelevant Alternatives
KW	KiloWatts
LCOE	Levelised Cost of Energy
LGA	Local Government Area
LG	Local Government
MW	MegaWatts
MLG	Multi-level Governance
MNL	Multinomial Logit
MTCP	Multi-Tier Coordination Platform
NERC	Nigerian Energy Regulation Commission
NDC	Nationally Determined Contributions
NGO	Non-Governmental Organisation
PAYG	Pay-As-You-GO
PV	Photovoltaic
RE	Renewable Energy

REDO	Renewable Energy Desk Officer
REMP	Renewable Energy Master Plan
RESs	Renewable Energy Sources
RETs	Renewable Energy Technologies
SHS	Solar Home Systems
SDG-7	Sustainable Development Goal-7
SG	State Government
SME	Small Medium Enterprises
SSA	Sub-Saharan Africa
PV	Photovoltaic
VIF	Variance Inflation Factor

1 INTRODUCTION

1.1 Background and motivation

The transition of energy systems from reliance on fossil fuels to renewable sources, given the alarming impact of climate change, represents one of the most significant challenges faced by governments globally [1]. The adoption of renewable energy (RE) in Sub-Saharan Africa (SSA) can lead to improved energy access, which is essential for driving economic growth and enhancing the quality of its inhabitants' lives [2–5]. By investing in RE infrastructure, countries in the region can create jobs, stimulate local economies, and increase energy security [3,6]. Moreover, RE projects can contribute to reducing greenhouse gas (GHG) emissions and combat climate change, which is crucial for the region's vulnerability to its impacts [7].

The increased adoption of sustainable energy systems has emerged as a cornerstone strategy for achieving global objectives, particularly Sustainable Development Goal 7 (SDG-7) [8]. Advancing SDG-7 requires a multi-dimensional approach encompassing global commitments to emission reduction targets, national efforts to formulate and implement sustainable energy policies, and the development of localized strategies tailored to energy consumption patterns [9]. Harnessing indigenous knowledge and localized strategies must also be prioritized by fostering public engagement to accelerate the transition toward net-zero emissions [4]. In this context, the development of sustainable energy policy frameworks becomes crucial, requiring a critical evaluation of adaptable systems that can accommodate the diverse socio-economic and political contexts of different regions. A standardized, one-size-fits-all approach to energy transitions is both impractical and ineffective given the variability in community needs and resources [10,11].

Globally, there is a growing call to transition from centralized, fossil-fuel-based energy systems to more decentralized, low-carbon models [8,12]. In many regions of the global south, centralized energy grids have failed to stimulate the expected economic development, especially in rural areas [13]. This shortfall has led to the emergence of a more decentralized, bottom-up approach, which includes citizen-led initiatives [14–22].

Such initiatives are increasingly seen as crucial to the decarbonization of the energy sector, marking a significant shift in the role of end-users from passive consumers to active participants, or prosumers [8].

Sub-Saharan Africa holds vast potential for the development of RE, with West Africa, in particular, having significant capacity for solar photovoltaic (PV) energy due to its high levels of solar irradiation [23–25]. However, the region's current utilization of this potential remains notably low. Despite accounting for 17% of the world's population, SSA contributes only 4% to global power supply investments and has installed just 5 gigawatts (GW) of solar PV capacity, representing less than 1% of the global total [26]. Moreover, the region grapples with substantial energy poverty, as over 55% of the population still lacks access to energy, highlighting a profound energy deficit [27,28]. Experts argue that fostering local solutions and engaging diverse stakeholders can accelerate RE adoption in emerging economies like Nigeria, contributing to both national and global climate goals [29,30].

Transitioning to RE offers significant benefits, including enhanced energy access, economic development, job creation, and greater energy security, while simultaneously reducing GHG emissions [2,6,7,31]. The International Energy Agency (IEA), 2019 [26], further asserts that achieving a stable and reliable energy supply in West Africa would require nearly quadruple current investment levels to approximately \$120 billion per year by 2040. Given the financial constraints faced by governments in low-income regions [32,33], state funding and international aid alone are insufficient to meet these investment needs. Consequently, there is a growing consensus that active citizen involvement in shaping local energy solutions through Community Renewable Energy (CRE) initiatives is essential to bridging this gap [17,20,34,35].

1.2 Research Gap

In line with this need for greater citizen participation, off-grid RE systems led by individuals and private entities are increasingly recognized as the future of electrification in African countries [36–38]. Despite this, individuals in SSA are often overlooked as key financial actors in energy transitions, partly due to assumptions rooted in widespread poverty and low household savings [39]. However, empirical data suggests a more complex reality.

Studies show that citizens collectively spend billions of dollars annually on the purchase and upkeep of diesel-powered generators—often out of necessity rather than voluntary capacity or choice [40–44]. In Nigeria alone, households and businesses allocate approximately \$12 billion each year to generator fuel and maintenance [45,46]. A trend corroborated by a Bloomberg survey [42]. With an estimated 22–60 million generators in the country—exceeding the national grid’s capacity by a factor of eight [47]. While this expenditure does not negate poverty, it does highlight a form of energy distress spending that could, if redirected and supported by appropriate policy and finance mechanisms, contribute toward decentralized renewable energy adoption. For instance, assuming a conservative cost of \$1,000 per kilowatt, this annual outlay could theoretically support the deployment of over 10 GW of solar PV capacity. This underscores the latent investment potential within households—if enabled through affordable, accessible, and sustainable alternatives.

Beyond their economic burden, fossil fuel-powered generators pose severe public health risks and significantly contribute to global GHG emissions. This research argues that actively engaging citizens in RE initiatives across SSA, particularly in Nigeria, offers a transformative pathway to localized energy transitions. Such engagement not only contributes to Nationally Determined Contributions (NDC), enhanced climate change awareness and shared environmental responsibility, but also represents a critical opportunity to shift private energy investments from fossil fuels to cleaner, more sustainable sources, thereby redefining energy governance and accelerating the socio-technical transition to renewables.

Despite considerable investments, policies and attempts to liberalize Nigeria’s energy sector, the nation is energy poor and continues to be stuck in a state of carbon dependency. In response to this issue, the implementation of CRE, an emerging concept in Nigeria, presents a socially-driven alternative solution [48] for transitioning away from carbon-intensive energy systems to sustainable alternatives. Scholars like Bauwens, [49], Herbes et al., [50] and Kalkbrenner & Roosen, [51], contend that it is imperative to understand the factors driving citizens’ involvement in CRE to hasten the socio-technical

transition to sustainable energy systems [52]. This necessity arises from CRE's pivotal role in facilitating the shift towards sustainable and low-carbon energy systems [53].

While a growing body of literature explores citizen participation in energy transitions, much of it remains concentrated on global North contexts—where determinants such as high education levels, environmental awareness, and affluence often drive participation in CRE. These factors, however, may not translate uniformly to SSA settings, where contextual dynamics—such as institutional fragmentation, local governance constraints, and socio-political realities—differ markedly from Eurocentric environments [35,54]. Although some studies have examined household participation in energy transitions within SSA and Nigeria specifically, a notable gap remains in understanding how decentralized governance frameworks can shape inclusive, citizen-led CRE adoption.

This research addresses that gap by advancing an Afrocentric outlook¹ on CRE participation, grounded in governance context of Nigeria's energy transition. It contributes not only an empirical analysis of the socio-economic determinants of CRE adoption but also proposes and tests the CRE–MLG framework—an innovative model that emphasizes multi-level governance, local accountability, and community engagement. In doing so, the study offers insights that extend beyond Nigeria, informing sustainable energy transition policies across the region and enriching broader discourses on energy justice, net-zero transitions, and the importance of inclusive, participatory models within the Global South.

Nigeria's energy policies and implementation strategies typically follow a top-down, centralized model, which creates gaps in the engagement and roles of mid-level and local government actors. This research presents a policy framework aimed at promoting sustainable energy practices among citizens, with the active participation of both state and non-state stakeholders at all levels. To achieve this, the research draws from multi-level governance (MLG) literature to construct a conceptual framework based on MLG theory, which clearly defines the roles and responsibilities necessary for these entities to

¹ An Afrocentric perspective, as used in this study, refers to an analytical approach that contextualizes Community Renewable Energy (CRE) adoption within the socio-economic, political, and cultural realities within the geographical boundaries of sub-Saharan Africa (SSA), rather than applying generalized frameworks developed in Euro-American contexts (*See Chapter 3-Para 6*)

effectively support the implementation of CRE in Nigeria. The innovation here is the proposed CRE-MLG framework, validated by quantitative and qualitative empirical analysis, emphasizing a collaboration between federal, state, and local governments, specifically, through the introduction of Renewable Energy Desk Officers (REDOs) at the local government level. The goal is to enhance the inclusivity and reach of RE within communities and foster active citizen engagement in adopting MLG as a sustainable, grassroots-driven energy approach. This framework is especially relevant for SSA countries with low-carbon transition goals, where government involvement is key to the success of CRE projects [55,56]. Additionally, the study addresses the lack of CRE-focused literature within the Nigerian context, contributing to the broader knowledge of CRE in SSA countries.

Furthermore, this research can contribute to broader discussions on democratizing RE transitions, ensuring that participation opportunities are inclusive and accessible to all sectors of society, irrespective of educational background or socio-economic standing. It also addresses the scarcity of literature on CRE in Nigeria and comparable SSA settings. The thesis delivers actionable recommendations for crafting RE policies in SSA countries with varied political systems, while also laying the groundwork for future research. Ultimately, the research promotes a socio-technical transition towards sustainable, citizen-focused energy solutions, aiming to overcome carbon dependence and propel low-carbon energy transitions in Nigeria, SSA and other global south regions.

1.3 Nigeria case study

Nigeria's size, geopolitical influence, unique biophysical characteristics, combined with its status as the most populous country in Africa, position it as a compelling case study for SSA within the context of this thesis. Despite its significance in the region, Nigeria faces the challenge of having over 90 million people without access to electricity [57–59]. Decades of governmental efforts and policies aimed at achieving universal electrification have proven largely unsuccessful. Additionally, Nigeria's substantial solar irradiation potential, along with its dispersed population clusters, underscores the importance of CRE as a key solution for meeting its national energy targets and fulfilling its Nationally Determined Contributions (NDCs) to address climate change. CRE offers an inclusive

pathway to achieve the country's ambitious "energy for all" objectives and ensuring that "no-one-is-left-behind". This makes Nigeria a central focus for exploring sustainable energy solutions in this research.

1.4 Research Aims and objectives

This research aims to **construct a sustainable energy governance framework that facilitates the development of Community Renewable Energy (CRE) policies for Nigeria's energy transition, drawing inspiration from exemplar countries such as Germany and Denmark.** These countries were chosen due to Germany's well-established citizen-led energy cooperatives and Denmark's decentralized energy governance system, both of which offer valuable lessons for fostering active public participation in renewable energy transitions. However, there are inherent tensions in using examples from the Global North to address challenges in the Global South, as the socio-economic and political contexts differ significantly. However, examples in the Global South are lacking. This tension underscores the data gap that this study seeks to fill by adapting these international models to Nigeria's unique energy landscape. The limitations of such comparative analyses, including differences in institutional frameworks and resource availability, are acknowledged and mitigated by grounding the proposed framework in Nigeria's specific realities. The resulting framework adopts a 'bottom-up' approach, integrating CRE and MLG to create a sustainable platform for active citizen participation in the energy transition. Moreover, this model is designed to be adaptable for other SSA countries, providing a replicable and inclusive strategy to address shared regional energy challenges.

A set of objectives has been established to accomplish this aim. Table 1-1 illustrates the connections between the identified research gaps and these objectives:

1. Analyze the development of CRE, particularly in Germany and Denmark with a view to identify key success factors in role of citizens' engagement in RE transitions via a comprehensive literature review.
2. Develop a conceptual framework that elucidates the interconnections and interactions between MLG and CRE, fostering the development of CRE within the Nigerian renewable energy landscape via literature review.

3. Employing a mixed methods approach, test and validate the framework by, a) identifying the determinants of CRE acceptance and adoption in Nigeria based on statistical findings and b), drawing on semi-structured interviews to assess the enablers and barriers for CRE-implementation by policy makers.
4. Leveraging insights from objective 1-3, provide policy recommendations regarding the development of CRE in Nigeria, with a focus on the potential roles and responsibilities of state and non-state actors, and implementation strategies.

Table 1-1. Relationship between research objectives and research gaps in the thesis.

Research gaps	Objectives			
	1	2	3	4
Limited CRE literature, particularly SSA	x	x	x	x
Limited MLG literature, particularly SSA	x	x	x	x
Limited quantitative analysis for determinant factors of CRE up-take in Nigeria			x	
Limited thematic knowledge on existing roles and responsibilities for RE actors across multi-tiered government authorities			x	
Limited knowledge on the roles of local government (closest government to the people) in CRE adoption		x	x	x
Limited literature on CRE policy adoption in energy transition in Nigeria	x	x	x	x
Limited knowledge of citizens' capacity to finance CRE	x	x	x	x

Dark and light shaded cells represent chapters with significant and moderate coverage of gaps respectively.

1.5 Research Methodology

The research methodology provides the foundation for investigating the dynamics of CRE adoption within Nigeria's socio-political and economic landscape. Considering the study's

ontological grounding in Critical Realism (CR) [60–63] and its epistemological alignment with social constructivism [64–66], a mixed-methods approach was adopted. This methodological choice is driven by the need to bridge gaps identified in the literature — requiring both quantitative data to uncover trends and patterns and qualitative insights to provide deeper interpretive meaning. By integrating both approaches, this study ensures a comprehensive exploration of CRE adoption, capturing both its breadth (quantitative analysis) and depth (qualitative perspectives). Furthermore, mixed methods enable triangulation, enhancing the credibility and robustness of findings by validating results through multiple data sources.

1.5.1 Rationale for the Research Approach

Given the interdisciplinary nature of energy transitions—spanning technological, economic, policy, and behavioral dimensions—a single-method approach would be insufficient. The decision to employ sequential exploratory mixed methods was informed by the following factors:

- **Complexity of Energy Transitions:** Energy transitions involve a mix of structural, behavioral, and policy factors, necessitating a multi-dimensional research strategy.
- **Triangulation and Cross-Validation:** Integrating quantitative surveys with qualitative interviews allows for data validation, reducing the risk of bias and improving result reliability.
- **Context-Specific Insights:** Quantitative methods reveal broad trends in citizen willingness to engage with CRE, while qualitative analysis uncovers the underlying motivations, barriers, and governance mechanisms influencing these behaviors.
- **Policy Relevance:** By blending statistical data with contextual narratives, this study generates actionable evidence-based policy insights rather than abstract theoretical conclusions.

Thus, a sequential exploratory design was adopted, where quantitative methods (see Chapter 3) provided initial insights, followed by qualitative methods (Chapter 4) that explored emergent themes in greater depth. Findings were then triangulated to derive holistic conclusions.

1.5.2 Research Philosophy

The study is rooted in the Critical Realist (CR) paradigm [60], which offers a nuanced approach to understanding the layered and emergent nature of socio-technical systems like CRE. CR's foundational principles are particularly suited to this study for the following reasons:

- Reality is Stratified: CR differentiates between three levels of reality—the real (causal mechanisms), the actual (observable events), and the empirical (human experiences) [62,67]. This approach allows the study to move beyond surface-level correlations and investigate the underlying structures shaping CRE adoption.
- Knowledge is Fallible but Evolvable: While reality exists independently, human understanding of it is inherently imperfect and evolving. This supports the study's iterative engagement with policy, governance, and behavioral dynamics [68,69].
- Emergence and Systemic Interactions: CR recognizes that interactions between actors—citizens, government, and the private sector—can generate new emergent properties, reinforcing the study's focus on co-created renewable energy systems [60,70].

Unlike positivist paradigms, which rely on fixed relationships between variables, or interpretivist paradigms, which focus exclusively on subjective experiences, CR provides a pragmatic balance, enabling a structured yet flexible mixed-methods research design [70].

1.5.3 Limitations and Mitigations of Research Approach

To ensure methodological rigor, several potential challenges associated with the mixed-methods approach were identified and addressed. These include time constraints, the need for proficiency in both qualitative and quantitative analysis, concerns about subjectivity in qualitative findings, and the complexities of data triangulation. Table 1-2 summarizes these limitations alongside the strategies implemented to mitigate their impact, ensuring a structured and credible research process.

Table 1-2. Limitations and Mitigation Strategies in the Research Approach.

Limitation	Mitigation Strategy
Time-intensive nature of mixed-methods research	Implemented a three-phased research plan with predefined milestones to optimize efficiency and manage time effectively
Skills required for both qualitative & quantitative analysis	Researcher undertook methodological training and sought expert guidance, particularly in STATA (quantitative analysis) and NVIVO (qualitative analysis), to enhance analytical proficiency
Potential subjectivity in qualitative findings	Employed Braun & Clarke's (2006) [71] systematic thematic analysis, ensuring transparency, consistency and reproducibility in coding and interpretation.
Challenges in data integration (triangulation)	Utilized a meta-matrix framework to systematically cross-reference survey data (quantitative) with interview insights (qualitative), strengthening the validity and coherence of findings.

1.5.4 Research Design and Methodological Approach

The overall research methodology, illustrated in Figur-1 unfolds in three key phases: Phase I—pre-fieldwork, Phase II—fieldwork, and Phase III—post-fieldwork. An iterative literature review was conducted throughout the research process to ensure that the study remained up-to-date with current developments in CRE. In **Phase I—pre-fieldwork**, the foundational work involved a comprehensive critical review of existing literature, which informed the development of the CRE-MLG framework. This phase also included the design and planning of the field trip, as well as the secondary data analysis that guided the fieldwork approach. During Phase II—fieldwork, the conceptual framework was empirically validated in northern Nigeria, where it served as the core case study of this research. This phase involved direct engagement with participants and key stakeholders on the ground through data collection. Phase III—post-fieldwork focused on data cleaning, screening and analysis to ensure that the results were robust, actionable, and reflective of the research goals.

This thesis argues that a mixed-methods approach is optimally suited to investigate socio-technical perceptions during the early stages of CRE adoption. Consequently, **Phase II—fieldwork** aligns with the idea that mixed-methods research capitalizes on the strengths of diverse paradigms [72]. By integrating both qualitative and quantitative methods, this approach enables a more comprehensive understanding of the complex interactions between social, technical, and governance factors influencing CRE adoption. It allows for the triangulation of data, providing deeper insights into stakeholder perceptions while enhancing the reliability and validity of the findings. This methodological alignment strengthens the capacity to address the multifaceted challenges of CRE implementation, supporting the argument that mixed methods are crucial for capturing the complexity of socio-technical systems.

As a mixed-methods research, Phase II addressed Objectives 3 and 4 by collecting both quantitative and qualitative data. The quantitative survey (n=559), conducted between August 9 and October 15, 2022, was analyzed using the MNL model to assess the likelihood of CRE adoption by Nigerian citizens, and the results are presented in Chapter 3. Following the survey, qualitative data was gathered from semi-structured interviews with (n=15) key stakeholders, conducted between October 20 and November 10, 2022. These stakeholders included RE investors, government representatives across various tiers, an academic expert in RE policy, heads of generation and distribution companies, and RE consultants. Their insights into CRE uptake and the challenges within Nigeria's energy landscape are detailed in Chapter 4.

In **Phase III—post-fieldwork**, the data collected was rigorously analyzed. The quantitative data from the survey was processed using the multinomial logit (MNL) model, which empirically validated citizens' readiness and willingness to adopt CRE initiatives. Concurrently, the qualitative data from the stakeholder semi-structured interviews was analyzed using Braun & Clarke's [71], six step data analysis process, provided deep insights of Nigeria's energy sector and the potential for CRE integration.

Each phase was systematically aligned with specific research objectives. Phase I addressed Objective 1 by conducting a comprehensive desktop review of global CRE adoption, particularly focusing on Germany and Denmark. This review identified key

success factors for citizen engagement in RE transitions and is reported in Chapter 2. This phase also developed the CRE-MLG framework, which links MLG and CRE, and laid the foundation for CRE advancement in Nigeria's RE landscape, fulfilling Objective 2.

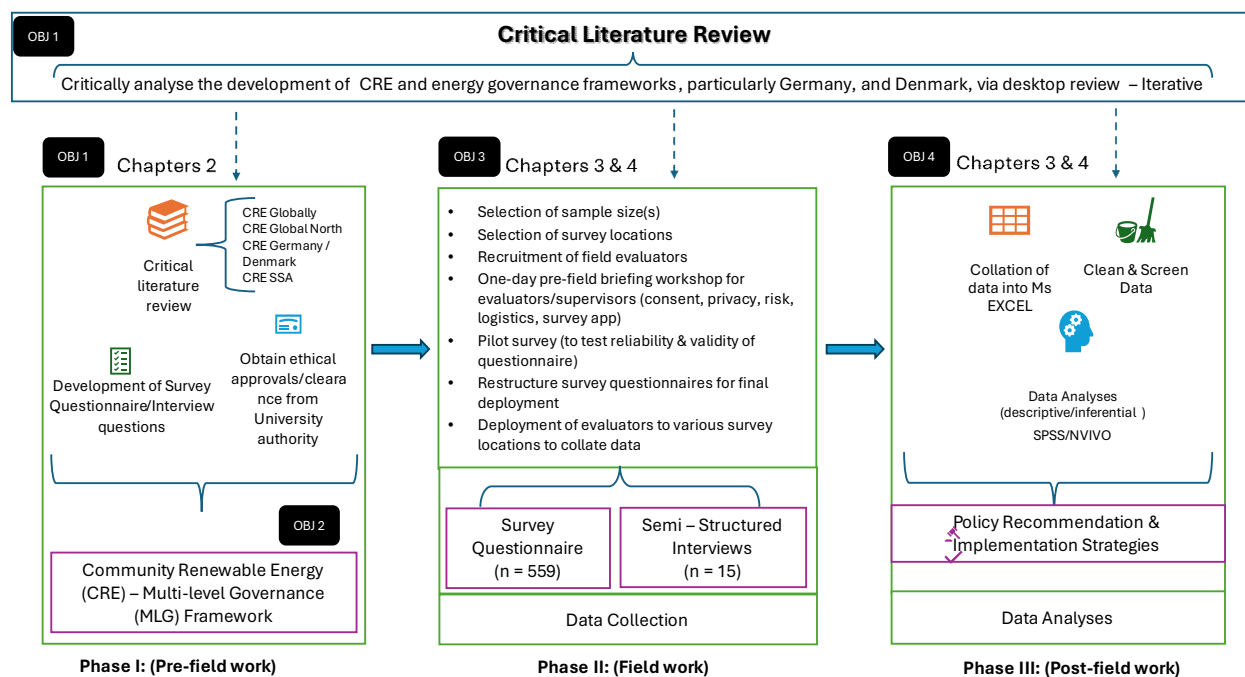


Figure 1-1. Research Overview Approach.

Phase II produced two significant outcomes. First, the survey results demonstrated a strong willingness among Nigerian citizens to participate in CRE projects, underscoring the essential role of local government actors in bridging the gap between community needs and national energy policies. Second, the semi-structured interviews validated the CRE-MLG framework, highlighting the importance of establishing REDOs at the local government level to facilitate CRE adoption across the country. These findings, which fulfilled Objectives 3 and 4, provided empirical support for the CRE-MLG framework its implementation.

In addition to the outcomes from Chapters 3 and 4, which are part of Phase III—post-fieldwork, Chapter 5 builds on these findings by offering targeted recommendations for policymakers and investors. These recommendations aim to improve the structures that facilitate CRE adoption in Nigeria, drawing from both the quantitative and qualitative

insights collected during fieldwork. Finally, Chapter 6 outlines the thesis' empirical contributions to knowledge, discusses its limitations, and offers recommendations for future research in the field of energy governance and CRE adoption.

1.6 Thesis Outline

The thesis is presented as chapters in paper format. A literature review and conceptual framework paper has been published in *Energy Research and Social Science (ERSS)* (Chapter 2), the quantitative paper (Chapter 3) is currently under review in *Energy Policy* journal, and the qualitative paper (Chapter 4) has been submitted for review in *ERSS* journal as well. The structure of this thesis is illustrated in Figure 1-2. While the content, starting from Chapter 2 of the thesis is presented as follows:

Chapter 2: This chapter establishes a 'Community Renewable Energy-Multi-Level Governance (CRE-MLG) framework' tailored for the implementation of CRE in Nigeria, drawing from a thorough analysis and synthesis of existing CRE and MLG literature. It also examines Germany and Denmark as countries with successful CRE initiatives, aiming to adapt, contextualize and institutionalize these models for the Nigerian energy landscape. The novel concept of Renewable Desk Officer (REDO) at all local government areas is first introduced as a conceptual institution in this Chapter. The framework offers policy considerations for Nigeria and identifies conditions under which elements could be adapted elsewhere, any relevance beyond Nigeria is illustrative and should be validated empirically. Ultimately, it advocates for a shift towards sustainable, citizen-centric energy practices to break free from the carbon lock-in and drive low-carbon energy transitions in Nigeria (with any relevance beyond Nigeria treated as illustrative). The insights and findings from this chapter form the foundational basis for the subsequent chapters. While country-specific, these insights may inform parts of SSA where institutional conditions are comparable; transferability should be established empirically.

Chapter 3: Building on the CRE-MLG framework developed in the previous chapter, this chapter focuses on identifying the determinants of citizen readiness to adopt CRE in Nigeria using a multinomial logit (MNL) model estimated in STATA and interpreted via average marginal effects (AMEs). Using six states in Northern Nigeria as case study, the

analysis ($n = 559$) shows income, education, and awareness as the most consistent predictors, with occupation adding nuance (civil service/NGO > informal); gender is not significant once controls are included. Interaction terms indicate diminishing returns to generic awareness at higher incomes and education-sensitive effects, confirming that adoption is not linear. Robustness checks (Independence of Irrelevant Alternatives (IIA), Variance Inflation Factor ($VIF < 5$)) are reported. While country-specific, these insights may inform parts of SSA where institutional conditions are comparable; transferability should be established empirically.

Chapter 4: This chapter builds on the novel concept of REDOs at the local government level. The REDO initiative represents a practical addition to Nigeria's existing energy governance framework, creating a dynamic support system for energy actors who directly oversee and implement national energy policies. By establishing REDOs in various local government areas, the CRE-MLG framework is operationalized, providing a structured platform for citizens to actively engage in the energy access dialogue while harmonizing with Nigeria's intricate energy governance system. Interviews with 15 state and non-state stakeholders identify fragmented mandates, slow approvals, and weak accountability as key obstacles and further validate the CRE-MLG framework. The thematic analysis offers a foundation for understanding how proximate, credible institutions enable energy access through the CRE-MLG framework. Additionally, the qualitative analysis offers operational perspectives on navigating and restructuring Nigeria's complex energy governance landscape, enabling greater citizen participation in the process.

Chapter 5: This chapter provides a comprehensive discussion of the thesis findings, synthesizing the results from all previous chapters. It integrates the quantitative evidence (e.g., AMEs and interactions from Table 3-3; Fig. 3-4) with qualitative stakeholder insights to show that adoption increases where affordability, education, and trusted local delivery align (REDOs). It also draws connections between the various outcomes and examines the broader implications of the research for policymakers, particularly in Nigeria. Policy implications beyond Nigeria are illustrative rather than prescriptive and depend on governance capacity, financing instruments, and delivery institutions that vary across Sub-Saharan Africa.

Chapter 6: The final chapter presents the thesis' empirical and methodological contributions to knowledge. It also identifies the key limitations encountered during the research and provides recommendations for future research on policy advancements in energy governance and CRE in Nigeria (with transferability to other settings established empirically).

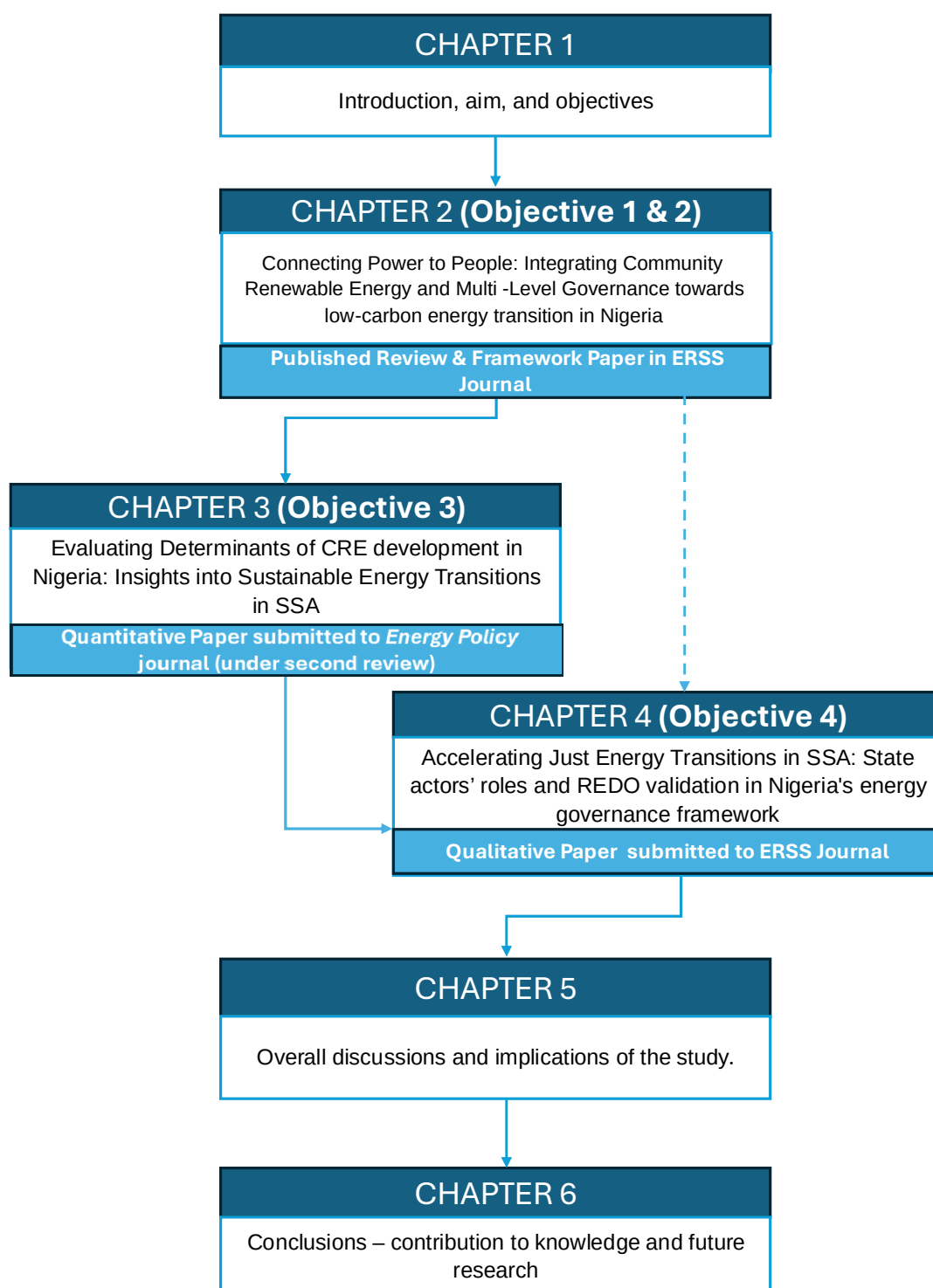


Figure 1-2. Thesis structure and interconnections between chapters.

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2 CONNECTING POWER TO PEOPLE: INTEGRATING COMMUNITY RENEWABLE ENERGY AND MULTI-LEVEL GOVERNANCE IN NIGERIA²

**Kim Kaze, Nazmiye Balta-Ozkan, Elisabeth Shrimpton*

Abstract

Despite extensive investments and deregulation efforts, the issue of carbon lock-in persists in the Nigerian context and across much of sub-Saharan Africa (SSA). Recognizing the value of citizen involvement in shaping energy transformation, this research advocates for the adoption of community renewable energy (CRE) in Nigeria. Drawing inspiration from paradigmatic CRE models in Germany and Denmark, the study explores the evolving landscape of low-carbon energy transitions in developing economies through the Nigerian case. Currently, Nigeria's low-carbon transition remains constrained by inadequate policies and top-down energy strategies, motivating the need for a more inclusive and decentralized approach. To address these challenges, this paper proposes a policy framework grounded in multi-level governance (MLG) theory. The conceptual framework delineates the roles and responsibilities of federal, state, and local governments, highlighting the scope for introducing renewable energy desk officers at the local level. Crucially, this research contributes to the limited body of CRE literature within Nigeria and similar sub-Saharan African contexts. The output provides concrete recommendations for renewable energy policy development in SSA nations with diverse political landscapes, in addition to supporting the future research agenda on CRE. Accordingly, the proposition of community renewable multi-level governance (CRE-MLG) reflects the rationale that citizen-centric energy practices can strengthen sustainability pathways in challenging contexts such as Nigeria. In contributing towards the burgeoning literature on energy transitions, this study advocates for an integrated governance approach and the bottom-up adoption of CRE practices to help drive sustainable development.³

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[https://authors.elsevier.com/sd/article/S2214-6296\(25\)00019-2](https://authors.elsevier.com/sd/article/S2214-6296(25)00019-2)

³ CRE, Community renewable energy; CRE-MLG, Community renewable energy multi-level governance; DRE, Decentralized renewable energy; EU, European Union; FiT, Feed-in Tariff; FG, Federal Government; GHG, greenhouse gas; FG, Federal Government; LG, Local Government; MLG; Multi-level governance; OECD, Organization for Economic Cooperation and Development; RE, Renewable energy; REDOs, Renewable energy desk officers; RESs, Renewable energy sources; SG, State Government; SSA, sub-Saharan Africa.

Keywords: Community renewable energy; Energy policy; Energy transitions; Multi-level governance; sub-Saharan Africa; Sustainable development

Highlights

- Examines the link between community renewable energy and multi-level governance in Nigeria
- Recommends integration of mid-level and local government in national energy policy
- Promotes community renewable energy adoption and citizen involvement in rural Nigeria
- Advances scholarly understanding of low carbon transitions in sub-Saharan countries.
- Provides an innovative policy solution for implementing energy sector reforms

2.1 Introduction

As Nigeria's energy demand continues to grow, integrating national renewable energy (RE) objectives with local energy planning presents an increasingly critical opportunity for overcoming fossil fuel lock-in [1,2]. Diversifying the electricity mix and improving energy efficiency, while accounting to citizens' opinions and preferences is crucial for supporting sustainable development in Nigeria [1,2]. Despite decades of significant investment and financial support, including a €165 million grant from the European Union (EU) for RE projects [3] and over \$1 billion in funding from other sources [4,5], Nigeria's peak energy capacity remained limited to around 5,000 MW in 2021 [6–8]. Faced with this shortfall, there is a growing imperative to seek alternative and innovative solutions [9], which can help bridge the gap for meeting a power requirement of at least 33,000 MW [10]. In view of this deficit and historical failures [11], off-grid RE led by individuals and private entities holds significant potential for accelerating electrification in Nigeria.

In the context of sub-Saharan Africa (SSA), one factor contributing to the lack of recognition of individuals as financial players is poverty and low savings rates [9]. Nevertheless, Dalberg [12], a nonprofit research organization, argues that energy insecurity in Nigeria led citizens to spend ~\$12 billion annually on hydrocarbon-powered portable generators, as further corroborated by Bloomberg [13]. Besides harming public health, reliance on these generators exacerbates global greenhouse gas (GHG) emissions. Nigeria has at least 22 million and up to 60 million such generators [14], which is eight times the capacity of the national grid. Given the substantial level of spending on generators and inadequate supply of power [15], market dynamics in Nigeria may enable a tangible shift to a cleaner energy system through low-carbon substitutions [16].

Despite significant investments and efforts to deregulate Nigeria's energy sector, the country remains trapped in a state of carbon lock-in. To address this challenge, the adoption of community renewable energy (CRE) offers an alternative strategy to strengthen decarbonization prospects. Notably, a recent study by Delina [17] confirms the increasing importance of citizen engagement in energy transformation, emphasizing

citizens as the *sine qua non* of ensuring energy availability. At its core, CRE is a decentralized, non-governmental approach involving the voluntary commitments of communities, citizens, and residents to promote the generation and utilization of renewable energy sources (RESs) and technologies [18].

As reviewed in Section 4, Germany and Denmark provide exemplars of countries where CRE is thriving, and insights can be drawn. In 2012, ~47-50% of decentralized RE capacity installed in Germany belonged to citizens and communities [19]. Similarly, the Danish energy transition is a widely studied example of a successful shift from fossil fuels to RE with strong community participation, serving as a paradigmatic model for burgeoning CRE initiatives globally [20]. Both Germany and Denmark attribute the growth of CRE to successful policies implemented since the 1990s, aimed at promoting and engaging citizens in decision-making and RE system management [21].

Although the financial stability of citizens typically reflects a critical success factor of CRE, Menyeh [9] argues that current spending on hydrocarbon-powered generators could provide sufficient capacity for replicating the success of European countries in SSA. Despite the apparent potential for consumers to adopt low-carbon technologies, inadequate policies impede the feasibility of this pathway in Nigeria [22]. To date, energy policies and implementation strategies have adopted a top-down, heavily centralized approach, which has resulted in structural gaps in the roles of mid-level governments and local governments actors.

In response, this study aims to develop a policy framework for supporting the adoption of CRE in Nigeria through a multi-level governance (MLG) approach. To support this aim, the initial research objective involves identifying critical patterns and gaps in the literature by analyzing how CRE scholars have engaged with social, economic, and environmental components underlying the sustainability triangle. The second research objective focuses on drawing insights from CRE-related developments in Germany and Denmark to better understand opportunities for replicating success in Nigeria. Recognizing the context-specific nature of CRE and need for adaptive mechanisms, the final research objective centers on explicating the value proposition of community renewable energy multi-level governance (CRE-MLG) by identifying and delineating the potential roles and

responsibilities of state and non-state actors in Nigeria. Leveraging insights from the Nigerian case, the proposed framework supports the wider goal of sustainable development by promoting active citizen participation and community empowerment towards realizing a low-carbon energy future.

Following this introduction, Section 2.1 provides an overview of multi-level governance to contextualize the tenets of this analysis. Next, Section 2.3 reports the research methodology, which is followed by a review of CRE-related literature in Section 2.4. Section 5 introduces the Nigerian case study, while Section 2.6 expands the theoretical lens by distinguishing between two types of MLG. Section 2.7 visualizes the proposed framework and discusses the value proposition of CRE-MLG. Finally, Section 2.8 concludes by outlining implications for policy makers and future research opportunities.

2.2 Multi-level Governance

Governance encompasses the multifaceted processes of formulating, implementing, and legitimizing public policies [23]. It involves cooperation between public and private institutions to guide and manage society, organizations, and networks [24]. Initially, "governance" typically denoted the complicated and uncertain conditions that constitute governing [25]. Governance entails achieving consensus, obtaining permission, or ensuring compliance to implement policies, projects, or strategies in arenas with diverse interests, distinguishing it from a top-down, government approach [24], [26]. In this context, low-carbon governance involves a multi-level process involving state actors, non-state actors from various industries, and local community stakeholders.

2.2.1 Theoretical background to multi-level governance

Multi-level governance (MLG), introduced by Gary Marks in 1993 [27], seeks to decentralize and liberalize governance and authority. Marks [28] initially defined MLG as an ongoing negotiation system among governments at various geographical levels, including supranational, national, regional, and local tiers, shaped by institutional developments and decision-making reallocation. In recent years, MLG has gained importance in reshaping energy governance [24,29,30]. To achieve RE targets effectively, climate and energy governance should engage all governance levels, from national to municipal [29].

Given the pivotal role of finance in driving CRE implementation, collaboration between private and public sector actors is crucial. While citizens can pool resources for CRE efforts, deliberate state-led strategies for incentivizing CRE could significantly accelerate RE penetration rates in SSA. Thus, MLG involves interconnected governance processes with state (public) and non-state (private) actors, adapting to context-specific modes of engagement and collaboration [31]. Another governance perspective emphasizes coordination and alignment toward a shared purpose and meaning, involving public and private actors and resources [32]. This view suggests that communities, central to CRE initiatives, form integral components of the governance structure beyond the formal institutional levels [28].

Initially, scholars applied MLG to European and global politics to describe federalist organizations with power dispersed among levels and institutions [33]. These systems coordinate policies across various government levels through consensus-building, compromise, competitive pressure, or hierarchical control [34], [35]. However, as the global economy continues to evolve, mechanisms for developing, implementing, and monitoring public policies have become more complex, leading to different definitions of MLG [36].

According to Stilwell and Troy [37], MLG refers to challenges that arise when coordinating policies and plans across multiple levels of government and with other sectoral policies. Following Ringel (2017), challenges may include issues of authority, resources, and institutional constraints where tiers of government (top or bottom) must interact with various (state/non-state) actors to address public policy concerns. Previously, researchers described the European view of MLG as systems of continuous negotiation among nested governments at multiple territorial tiers [39], [40]. Nonetheless, studies have also failed to fully consider that authorities are horizontally distributed across sectors and spheres of influence [37,38], [39] [40], including non-state actors which form the core of the governance concept [41].

2.2.1 Alternative perspectives on multi-level governance

The concept of MLG serves as a mechanism to coordinate government efforts for more efficient policy implementation [42]. However, an alternative perspective on MLG [23]

proposes viewing it as a policy-dimensional framework, which is adaptable to local contexts and beneficial to countries. This perspective focuses on hierarchical levels of governance and explores attributes beyond geographical and bureaucratic boundaries, offering valuable insights for the formulation and implementation of Nigeria's CRE policies. Within the context of a diverse nation like Nigeria, characterized by its demographic heterogeneity, MLG emerges as a potent instrument for facilitating participatory decision-making processes in low-energy transition plans [21,23,40]. Such plans necessitate active engagement from both state and non-state actors, as well as residents, who articulate their interests, exercise their legal rights, and collectively address differences through collaborative methods [43].

MLG empowers regional and local governments with autonomy to mobilize resources independently of central government intervention [32]. However, it is important to highlight that MLG serves as a framework for researching political processes across multiple levels of government and scales within countries, rather than being a specific method [32,44]. Understanding the increasing engagement of non-state actors in governance processes [24] is crucial for grasping how MLG emphasizes "negotiated" and "non-hierarchical" linkages and interdependence among institutions and actors across various geographical borders [45]. It follows that MLG is highly relevant to empirically comprehending the modern state and the evolving dynamics of governance [42].

2.3 Research Methodology

In line with recent contributions to the energy transitions literature, this employs a *narrative* literature review [46–49], and undertakes country case studies to develop a conceptual framework for implementing CRE in Nigeria. Prior to reviewing CRE-based studies, mapping the Nigerian context, and elucidating insights on MLG [27], Section 2 frames the conceptual contribution by summarizing the theoretical foundations of MLG and key developments associated with this line of thinking [23], [36], [37], as depicted in Figure 2-1.

Following an initial scoping of the literature, which revealed a modest number of case studies on CRE, and in line with the aim to develop a conceptual framework, this study leverages insights from a multi-stage narrative literature review (see Section 4). Whereas

a systematic literature review (SLR) [50] [51–55] is a rigorous and replicable research method for synthesizing insights from a large evidence base (e.g. following the guidelines of PRISMA⁴), a narrative approach is better aligned to supporting exploratory research and qualitative insights [56], and for purposes of developing a future research agenda [57].

While a narrative approach involves synthesizing evidence familiar to an author on a corresponding research area [56], this study incorporates a structured approach by implementing specific search criteria to support its objectives. However, as opposed to following an iterative process by adjusting search strings or rigorously cross-checking results from several databases [56], this study relied exclusively on strategic filtering methods vis-à-vis subject matter, citation ranking, and journal impact factor, alongside collective evaluation between the research team to identify pertinent results.

The initial search commenced in September 2022 as part of a wider research project which involved field work in Nigeria. Following parallel analyses of qualitative and quantitative data retrieved via interviews with CRE stakeholders and surveys with local communities, the literature search concluded in September 2023, thereby facilitating an iterative research process and enabling triangulation of results within the wider project.

The first step involved retrieving academic studies⁵ by searching for ‘community renewable energy’ in Scopus and Google Scholar, which was supplemented via subsequent rounds of snowballing [58,59]. Saturation was reached once clear patterns between research engagement levels with the sustainability triangle (i.e. social, economic, and environmental pillars) could be observed and a range of research perspectives had been captured, which yielded a small to moderate sample (n=35). This starting point helped demarcate various aspects of CRE such as terminologies and definitions, organizational structures, competing ideas, nuances and research perspectives.

⁴ Preferred Reporting Items for Systematic reviews and Meta-Analyses [192]

⁵ Grey literature sources were excluded from the narrative literature review.

The subsequent procedure focuses on a more targeted search with the following keywords support the first research objective: 'community renewable energy' AND 'Germany' OR 'German'; and 'community renewable energy' AND 'Denmark' OR 'Danish'. Both Germany and Denmark have played a pioneering role in advancing CRE, and each context has been well researched. This research stage served as an opportunity to extract critical lessons regarding the potential drivers and barriers shaping prospects for CRE in Nigeria. Saturation was reached once 15 academic papers had been retrieved on each country context, since this volume of literature proved adequate for representing the most active research groups or highly cited studies. The quality of the small sample was further validated by carrying out a supplementary check via snowballing, which demonstrated high levels of interconnectivity between the retrieved evidence base.

Following critical engagement with the European perspective, Section 5 unpacks the context-specific nuances underlying the Nigerian case, recognizing the imperative to consider the distinct characteristics, expectations, and specific needs of citizens and local communities in the design and implementation of CRE initiatives [60,61]. In shifting attention to the Nigerian energy landscape, this stage drew on a combination of peer-reviewed articles and materials from the grey literature to understand policy developments and barriers to implementing CRE. The final research stage involved expounding on the two types of multi-level governance (MLG) and citing examples from the German and Danish context to consolidate the conceptual framework, as reflected via the integrated research procedure illustrated in Figure 2-1.

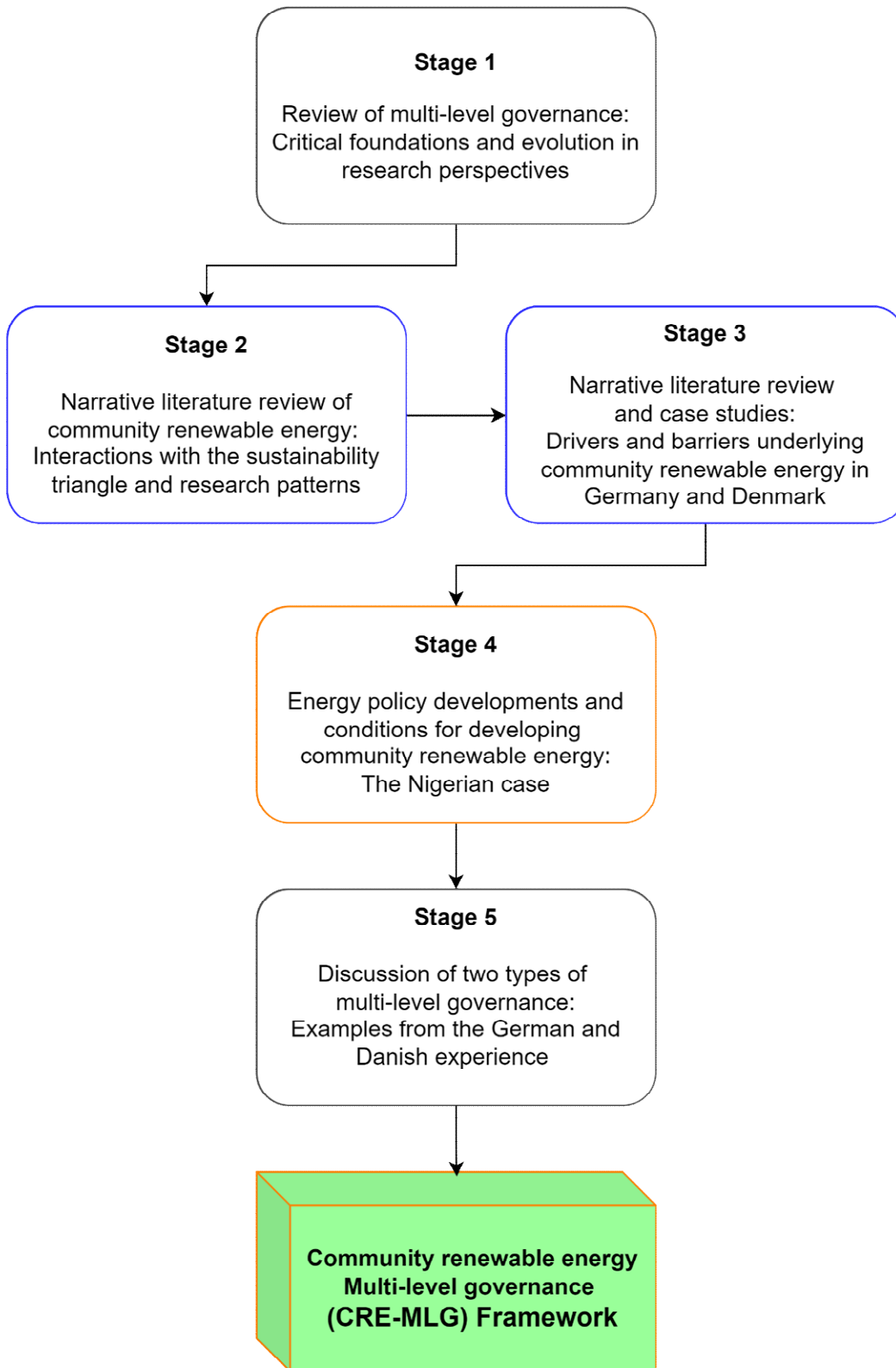


Figure 2-1. Research procedure integrating narrative literature review and case studies.

2.4 Literature Review on Community Renewable Energy

A 'community' can take various definitions, such as a group of people living in a particular location during a specific period [62], or a social grouping of any size of individuals who reside near one another geographically, such as a neighborhood, municipality, district, or urban area, where members can interact face-to-face [63]. Notably, Walker [64] constructed a 6-point vocabulary for the concept of community: actor, scale, place, network, process, and identity. Accordingly, the term community encompasses a broader conceptualization than simply a physical location, relating to shared politics, culture, interests, and social connections [65].

Scholars also differentiate between "communities of interest" and "communities of locality" when discussing community in energy systems. "Community of interest" refers to a group of individuals who share a common objective but are not necessarily situated in the same geographic area while "communities of localities" pertain groups of people who share a common geographic location [66,67]. Furthermore, Walker & Devine-wright [66] offer a community model that includes the two essential elements of CRE, outcome and process dimensions. The former reaps the social and monetary rewards i.e., who is the project for. While the process dimension includes questions such as who creates the project and actively involved participants i.e., who manages the project [18,67].

However, there is a lack of consensus regarding the definition of CRE, which often hinders the development of an effective policy design and obscures the differences between different forms of citizen ownership [28,29,31,32,33]. Depending on the researcher or environment, CRE, is usually contextual in nature with blurred boundaries depending on the country [68]. Given its many variations and terminological ambiguity, clearly demarcating the characteristics of CRE remains a research task.

This review of the literature juxtaposes the following collection of associated synonyms under the umbrella term CRE: sustainable energy communities (SEC), renewable energy communities (REC), community-based energies (CBE), citizens' ownership, citizens' energy, low-carbon communities, and sustainable communities, energy communities, community renewable initiatives, community energy projects, community renewable energy projects (CREPs), renewable energy community (REC), energy cooperatives,

local energy community and community energy [19,69–75]. Due to the lack of unanimity over CRE's definition, local context-specific approaches illustrate a range of CRE-related directions that may emerge [76]. For example, multiple studies undertaken in the UK [65,66,77] have documented business and legal models, motivations, objectives, actors and social connections in the field of CRE.

Existing definitions have a common feature, whereby CRE aims to redistribute benefits and decision-making authority to local communities through the collective administration of individuals to enhance their sense of ownership, involvement, and energy security. Three common threads that highlight the emerging interconnectedness of social, economic, and environmental variables within the realm of CRE. Specifically, the social dimension, which encompasses community participation and engagement, is a key and consistent aspect of all CRE definitions (see Table 2-1), whereas the environmental dimension stresses the mitigation of environmental impact, energy-efficient behaviors, and a reduction of carbon emissions. Additionally, the economic dimension of CRE focuses on the creation of financial gains, job opportunities and the enhancement of community value.

According to Purvis et al. [78], these three characteristics form the cornerstone of sustainability. Most CRE scholars highlight at least two variables in the sustainability triangle as pillars in defining CRE [79], as illustrated in Table 2-1. As an emerging sustainable model, CRE is an opportunity for citizens of SSA to join other members of the global community in confronting the environmental and social consequences of climate change, while also combating energy poverty and creating economic opportunities.

Table 2-1. Scholarly engagement with CRE within the sustainability triangle.

Source(s)	Social	Environmental	Economic
Sovacool [80]	X	X	X
Walker et al [66], [64]	X	X	X
Martiskainen [81]	X	X	X
Rogers et al. [82]	X	–	X
Seyfan et al. [77]	X	X	X
Kalkbrenner et al. [72]	X	X	–
Hicks et al. [83]	X	–	X
Schoor et al. [84]	X	X	–
Greenius et al. [63]	X	–	X
Mey [85]	X	–	X

Romero-Rubio et al. [75]	X	X	X
Middlemiss et al. [73]	X	X	–
Oteman et al. [18]	X	–	X
Oteman et al. [21]	X	X	X
Chaichana et al. [86]	X	–	X
Süsser et al. [87]	X	–	X
Sciullo et al. [88,89]	X	X	–
Ebers Broughel et al. [89]	X	–	X
Marquardt [90]	X	X	–
Curran [91]	X	X	–
Dobracev et al. [29]	X	X	–
Delina [17]	X	–	X
Magnoni et al. [92]	X	–	X
Toke [93]	X	X	–
Yildiz [19]	X	–	X
Luangchosi [94]	X	–	X
Menyeh [9]	X	–	X
Fernandez [95]	X	X	–
Becker et al. [96]	X	–	X
Lakshmi et al. [62]	X	–	X
Musall et al. [74]	X	–	X
Ringel [38]	X	X	X
Ohlhorst [97]	X	X	X
Salm et al. [98]	X	X	–
Mean frequency (%)	100	52.9	70.5

X denotes inclusion of CRE pillar.

– denotes exclusion of CRE pillar.

Most of the literature and case studies on CRE apply a European lens [77,87,99–103], [81], failing to consider the unique cultural and local factors that shape the development and execution of energy initiatives in non-Western countries. Consequently, studies with a citizen-centric focus [72,95,101,104] have failed to capture non-European perspectives of participatory processes in the energy transition. Additionally, researchers who have explored energy cooperatives [105,106] are yet to engage with case studies in the developing world. Arguably, Cloke et al's [107] paper provides the closest assessment of CRE in the context of developing economies in general, nonetheless, SSA was not the primary focus of their research. Although Lakshmi & Tilley [62] and Menyeh [9] discuss CRE and SSA, they prioritize a profit- version of decentralized renewable energy (DRE), as opposed to the pro-social CRE variant, although CRE is presented as a subtype of DRE [106].

The study of Ambole et al. [108] engages with the context of SSA, concluding that CRE can play a role in boosting energy access in Africa. However, the research lacks ideas

for policy and governance frameworks that could facilitate their development and implementation [108]. Other scholars underline the potential of RESs for meeting Africa's energy demand but fail to propose policy frameworks required for their implementation. For example, while Ibrahim et al. [109] and Ambole et al., [110] discuss the failure of policy execution in respect to (implementing) subsidies and tariffs. Boamah [111] present country-specific factors critical for DRE, whereas other studies [112–114] discuss mini and micro-grids markets as investment options, but none provide a clear solution relating to the governance framework for accomplishment. Despite Musonye et al's [115] recognition that prospective DRE solutions have effective implementation methodologies, their work did not elaborate on specific mechanism. Additionally, Nkoana [116] acknowledge the need for a participatory governance framework, without providing details on how to create one.

Modern energy production is centralized, primarily fossil-fuel-based, and dispersed widely. By contrast, the philosophy of CRE is grounded in decentralized, community-owned, small-scale RE facilities [94]. Therefore, for a community to be sustainable, it requires fossil fuel-to-RE transitions [117]. CRE promises such transitions through social transformational potential, enabling a democratic environment and participative bottom-up CRE projects [118]. At present, most countries are still in the process of determining the feasibility and suitability of implementing CRE in their specific geographic and socio-economic contexts [20]. Nevertheless, three fundamental components characterize the meaning behind CRE: it is a type of DRE system; it adopts any RE source; and its focus is on collaborative (communal) effort and citizen participation.

2.4.1 Ownership models and financing mechanisms

2.4.2 Ownership models for community renewable energy

Ownership models are critical to the success and sustainability of CRE, especially in developing economies such as Nigeria, where local socioeconomic, cultural and institutional contexts must be accounted for. Key examples include the community-owned model, cooperative model, public-private partnerships (PPPs) and third-party ownership.

The **community-owned model** involves direct community ownership and management of RE projects. It empowers local stakeholders and ensures that benefits, such as profits

and energy savings, are retained within the community. This structure fosters a sense of agency, social cohesion, and accountability, aligning with the principles of decentralization and inclusivity that underpin CRE initiatives [66,119].

Under a **cooperative model**, community members collectively own and operate renewable energy projects. Cooperatives have gained prominence in countries such as Germany and Denmark, where they have successfully scaled renewable energy transition by mobilizing investments and building local trust [120,121]. By pooling resources and decision-making power, this model exemplifies grassroots participation and democratic governance.

PPPs represent collaborative efforts between government entities and private sector players, combining public oversight and funding with private sector efficiency, technical expertise, and financial resources. These partnerships help bridge resource gaps and are particularly effective in scaling projects in resource-constrained regions like Nigeria [99,122].

Third-party ownership sees external organizations own and operate CRE projects, while communities receive energy services. Although this minimizes financial risks for communities, it often limits their involvement in governance. Strong contractual agreements, however, can ensure equitable benefit-sharing and accountability [83,123].

2.4.3 Financing mechanisms for community renewable energy

Alongside ownership models, innovative financing mechanisms can help address the capital-intensive nature of CRE projects while ensuring long-term sustainability and inclusivity. Prominent mechanisms include crowdfunding, grants and subsidies, revolving funds, green bonds and international climate finance, and Pay-As-You-Go (PAYG) models.

Crowdfunding democratizes investment by enabling individuals to contribute small amounts to RE projects. In rural Nigeria, leveraging local thrift systems—prevalent community-based savings mechanisms—can enhance resource mobilization for CRE. This approach fosters grassroots engagement, expands participation, and builds a sense of local ownership [19,123].

Government grants and subsidies provide essential catalytic funding, particularly for initial capital requirements. These incentives lower financial barriers, helping communities overcome economic constraints and unlocking broader socioeconomic benefits, such as improved health and education outcomes [119,122]. Subsidies also reduce dependence on unsustainable fossil fuel alternatives.

Revolving funds offer a sustainable capital flow mechanism by providing low-interest loans for RE projects, with repayments reinvested into the fund to finance future projects. This self-sustaining financing model, often managed by community organizations or cooperatives, ensures financial accountability and promotes long-term viability [99,124,125].

Institutional mechanisms such as **green bonds and international climate finance** are increasingly relevant for CRE initiatives. Green bonds provide large-scale, long-term financing linked to environmental goals, while climate funds (e.g., the Green Climate Fund) offer grants or concessional loans to promote RE transitions. These tools not only address financing gaps but also align CRE projects with global climate targets [126,127].

Finally, **PAYG models** facilitate incremental payments for energy services, often via mobile platforms. In their seminal work, [128] refer to “Fee-for-Service” as an example of a PAYG model in the context of supporting solar systems for rural households in South Africa. Such schemes are particularly effective in underserved regions where communities face limited upfront capital capacity but can afford small, regular payments. PAYG models help expand inclusivity and affordability, enabling communities to access clean energy without significant financial strain [66].

2.4.4 Community Renewable Energy in Germany and Denmark

As CRE spreads geographically and contributes towards reducing energy consumption, community-driven RE efforts are expanding rapidly within Germany and Denmark, while the UK is another CRE frontrunner [18,75]. In other industrialized nations, new public engagement initiatives, like RE advocacy and awareness campaigns are informing citizens about their role in advancing energy transitions [17].

Germany and Denmark have successfully employed CRE to support their sustainable energy objectives [47]. Both nations serve as paradigms, with Germany being a model for RE-powered industrialization while Denmark is renowned for its decentralized CRE ownership model, which originated with wind energy cooperatives in the late 1970s [20,129,130]. Since the 1990s, both countries have promoted CRE operations through regulations and efforts to expand RE project ownership [21]. Notably, Germany has actively promoted RE since 1991, when it enacted a renewable power feed-in-law making its energy economy and public RE delivery structure highly interventionist [18,131].

This section aims to extract lessons and common factors from the German and Danish cases to help identify the tenets for establishing CRE-MLG in Nigeria. The CRE-MLG approach entails pioneering a domestic and pragmatic transition towards a low-carbon society which necessitates the active involvement and collaboration of citizens and local communities. Accordingly, by reviewing how each country implemented policies and supported incentives to promote CRE (see Table 2-2), researchers can support progress in the Nigerian context. While CRE has proved integral to Germany's and Denmark's RE strategy, as reflected via a range of studies within the academic literature (see Supplementary Materials 1 and 2), a mix of drivers and barriers underlying the implementation of CRE are identifiable, which can support the learning curve in Nigeria.

Table 2-2. Comparison between key characteristics underlying the energy transition in Germany and Denmark.

Characteristics/features	Germany	Sources
RE Policy targets	<ul style="list-style-type: none"> 40-45% of power from RE by 2025 and 80% by 2050 	[132,133]
Government strategy/policies/legal framework	<ul style="list-style-type: none"> Energy Transition-<i>Erneuerbare Energien Gesetz</i> (EEG 2000) "<i>Energiewende</i>". 	[106,132,133]
Motivation	<ul style="list-style-type: none"> 1970s oil crisis; Chernobyl 1986 environmental crisis, anti-nuclear energy movement Economic/financial incentives (employment creation); community image; environment 	[73,97,134,135]
Actors	<ul style="list-style-type: none"> State: Federal, State (Laender), Local governments Non-State: RE cooperatives & associations 	[71,97,98,106]
Major regulatory body	<ul style="list-style-type: none"> Ministry of Economy and Technology 	
Role of local government	<ul style="list-style-type: none"> <i>Bürgerenergie</i> is a democratically run enterprise and government participation at all levels 	[71,106]
Governance structure	<ul style="list-style-type: none"> Decentralized bottom-up model at subnational levels. 	[18,72,106]
Ownership schemes & structures	<ul style="list-style-type: none"> Citizens' energy cooperatives and associations (<i>Bürgerenergie</i>) Citizens' collaboration between local governments (LG) and local actors Collective ownership widespread Varying cooperatives (<i>Energiegenossenschaften</i>) 	[18,98,132,133,136]
Financial incentives	<ul style="list-style-type: none"> The most subsidies worldwide Feed-in-Tariffs Act <i>Stromeinspeisegesetz StrEG</i> (1990) operational Deployment support (RE Sources Act EEG) A form of PPP between banking institutions (e.g., <i>Okostromgruppe Freiburg; GmBH Fesa GmBH</i>) and State/Federal Administration Local/regional subsidies and low interest loans Fossil fuels and other environmentally detrimental actions are taxed 	[18,19,75,80,98,106,137,138]
Dominant community-level renewable energy technology (RET)	<ul style="list-style-type: none"> Solar (photovoltaic) 	[106]
Progress level	<ul style="list-style-type: none"> Most installed solar PV globally in 2013 (36GW), surpassing 70GW in 2023 (Q1) Target 215GW by 2030 Approx. 50% of solar PV is community owned 	[19,106]
Community and citizens engagement	<ul style="list-style-type: none"> Citizens control approximately half of RE capacity and instrumental in the energy revolution. Citizens own most shares of CRE <i>Bürgerenergie</i>. 	[98,106]
Characteristics/features	Denmark	Sources
RE Policy targets	<ul style="list-style-type: none"> Wind turbines generated 26% of the nation's electricity by 2011 30% RE by 2025 100% RE by 2050 	[80,92]

Government strategy/ policy/legal framework	<ul style="list-style-type: none"> • Electricity Supply Act • National Renewable Energy Action Plan • Draft-National Energy and Climate Plan • Energy Strategy 2050, • National Recovery and Resilience Plan • Green Transition, Renewable Energy Act (2009) • Innovative democratic process • Denmark RE Policy Handbook, (2022) 	[20,68,139]
Motivation	<ul style="list-style-type: none"> • Energy net exporter • 1/3 world market for wind turbines 	[80]
Actors	<ul style="list-style-type: none"> • State: Federal, State and local government; The green majority in parliament. • Non-State: RE NGOs, <i>Organisationen for Vedvarende Energi (OVE)</i>; The Danish Wind Turbine Association; OOA Lobby organisation-advancing RE information discussion and dissemination 	[20,139,140]
Major regulatory body	<ul style="list-style-type: none"> • Department of Energy and Climate 	
Role of local government	<ul style="list-style-type: none"> • Part 1(3), Promotion of RE Act (2009) includes roles for municipalities. • Centralized 'coercion' in a legislative sense on involvement of local authority. • Establishment of federation of energy offices (SEK) in 1977 • CRE mobilized by partnership with local government authorities. • Local governments are required in their role as planning and approving authority to deliver share of national RE targets • Sub-municipality plans called strategic energy plans; stepdown from national RE plans. 	[20,93,139–141]
Governance structure	<ul style="list-style-type: none"> • Bottom-up decentralized approach • Local and regional cooperation with central government • Communities in charge of meeting ambitious RE national targets with local government support (<i>Kommuner</i>) • Delegated authority from Copenhagen to local municipalities 	[18,141,142]
Ownership schemes & structures	<ul style="list-style-type: none"> • Citizen-led bottom-up initiatives • Collective ownership widespread • Agriculture cooperatives in wind energy policy • Traditional cooperatives (<i>interessentskab</i>) led to the homogeneity of organization form for community wind projects 	[20,75,85,143]
Financial incentives	<ul style="list-style-type: none"> • Energy efficiency, long-term taxes on energy fuels, electricity, and carbon • Tax-free subsidies, investment grants and low-interest • FITs (1993) operational 	[20,92,139]
Dominant community- level renewable energy technology (RET)	<ul style="list-style-type: none"> • Wind turbines 	[20]

Progress level	<ul style="list-style-type: none"> • In 2017, Denmark had 4910 wind turbines, total installed capacity-5229 MW • About 20% (1082 MW) owned locally by citizen cooperatives. 	[68,85,142,144]
Community and citizens engagement	<ul style="list-style-type: none"> • Most wind turbine owners are local community investors. 	[67,92]

Table 2-3. Drivers and Barriers of CRE in Germany and Denmark.

Drivers	Germany	Denmark
Government policies and incentives	<ul style="list-style-type: none"> • The Act (EEG) allows for citizen participation in the form of community or citizen-owned energy cooperatives • Germany's <i>Energiewende</i> spurred CRE development • Community groups can develop and implement their projects using RE auction systems • Feed-in Tariffs: This financial structure assures a fixed price for RE [98,145] 	<ul style="list-style-type: none"> • Community groups plan and implement projects using the Feed-in Tarriff policy, Community Energy Development (CED) programme, and green certificate system • CRE in Denmark relies largely on state facilitation and subsidies • The institutionalization of CRE by providing financial and regulatory incentives for its operations [20,93]
Local Support and Participation	<ul style="list-style-type: none"> • Local authorities and communities support have been key to the development of CRE [96] 	<ul style="list-style-type: none"> • Long tradition of public participation, decision making and ownership of CRE has driven CRE's development [80]
Increasing public interest and awareness of RE	<ul style="list-style-type: none"> • Community RE involvement mobilizes project support [146] 	<ul style="list-style-type: none"> • Communication and training for RE awareness [92]
Economic benefits	<ul style="list-style-type: none"> • Energy savings, job creation, and local economic development [71,106] 	<ul style="list-style-type: none"> • Energy self-sufficient and net exporter reflecting in balance of payments [141]
Social benefits	<ul style="list-style-type: none"> • Community empowerment, enhanced social cohesion, and improved environmental quality [71] 	<ul style="list-style-type: none"> • Ensures broad participation of diverse actors [147]
Barriers	Germany	Denmark
Administrative procedures	<ul style="list-style-type: none"> • Complex and lengthy [71] 	<ul style="list-style-type: none"> • Administrative bottle necks exist [141]
Legal and Regulatory	<ul style="list-style-type: none"> • Lack of clear objectives, lack of standards and processes [148] 	<ul style="list-style-type: none"> • Lengthy planning process [68]
Financial constraints	<ul style="list-style-type: none"> • High initial investment costs and limited access to funding [98] 	<ul style="list-style-type: none"> • High initial investment costs and lack of access to finance [80]
Limited technical expertise	Smaller communities' difficulties grasping CRE technical and operational aspects [106,149]	<ul style="list-style-type: none"> • Technical expertise not widespread in all municipalities [92]
Limited public awareness/acceptance	<ul style="list-style-type: none"> • Low community participation and RE benefits understanding • Local community and stakeholder opposition can hinder their development [98] 	<ul style="list-style-type: none"> • Local communities and other stakeholders may oppose CRE projects preventing their implementation [80]

2.4.5 Germany

Citizen engagement has been the driving factor behind the growth and spread of RE in Germany [106], as reflected in findings in the literature (See SN1). Most German CRE projects are cooperatives popularly known as *Energiegenossenschaften*. About 970 such projects exist, corresponding to the largest shareholders of Germany's 36 GW installed solar and the most installed capacity globally [18,72,145]. The state-led *Energiewende* strategy promotes community activities that support energy policy [18]. The country's energy transformation relies on cogeneration and community engagement [72]. Table 1-3 highlights a particular political lesson Nigeria can learn from Germany as both countries have a federal structure. Due to distinct geographic, economic, and demographic frameworks, Germany's *Laender* (federal states) – like Nigerian states – may not necessarily share the national government's aims or policies [97]. As noted by Kalkbrenner and Roosen [18], the frequency and configuration of CRE may vary according to unique regional characteristics, while Sun and Baker [23] note MLG is flexible to local settings. This explains why *Bürgerenergie* – as a democratically managed enterprise – prioritizes community RET choice and most importantly government participation [106], offers an additional less for the Nigerian case.

2.4.6 Denmark

Denmark has the most decentralized RE use in Europe, with municipal administrations (*Kommuner*) possessing vast financial resources and autonomy in RE policymaking. Accordingly, multiple studies on the Danish case have been conducted by energy scholars, drawing on a range of research methods (see SN2). The institutional framework of Denmark includes local cooperatives which is a key part of governance and enabler for community action in RE programmes [18], [93]. The nation boasts the highest level of energy independence and sustainability in the Organisation for Economic Cooperation and Development (OECD), achieving self-sufficiency in energy production and consumption [80]. Following the 1973 oil crisis, Denmark shifted from a centralized fossil-fuel-based power network to one dominated by wind turbines and combined heat and power (CHP) units within two decades and has since maintained its leadership in wind energy [80]. Denmark's energy transformation has received significant funding through community involvement [127], with the government now aiming for a 100% RE grid by

2050 (see Table 1-2). Despite limited resources, municipal administrations (*Kommuner*) have energy policy autonomy and receive legislative and financial support from the national energy framework, especially in RE [18,20].

2.4.7 Insights from Germany and Denmark

While Germany's emphasis on citizen engagement has undoubtedly propelled its RE growth, questions arise regarding the inclusivity and equity of this approach [71,106]. Despite the proliferation of energy cooperatives, there are concerns about the accessibility of these initiatives to marginalized communities and the extent to which they truly empower citizens in decision-making processes [98]. Similarly, Denmark's decentralized governance model appears promising, but deeper analysis reveals potential pitfalls, such as disparities in local government capacities and resources, which may exacerbate inequalities in RE access and adoption [80]. Potential CRE-newcomers such as Nigeria must critically assess these models to ensure new initiatives are not only effective in promoting RE but also socially just and equitable.

Furthermore, while policy mechanisms such as Germany's Feed-in Tariff (FIT) and Denmark's cooperative ownership model have been instrumental in driving CRE progress, their applicability and effectiveness in the Nigerian context requires careful consideration. Questions arise regarding the scalability and sustainability of FIT schemes in a developing economy like Nigeria, where regulatory uncertainties and financial constraints may hinder private sector investments in RE. Similarly, while cooperative ownership models have demonstrated success in Denmark, challenges may arise in replicating this model in Nigeria's diverse socio-economic landscape, where issues of governance, trust, and transparency pose significant barriers [150,151].

While CRE initiatives in Germany and Denmark offer important lessons for Nigeria's energy transition, context-specific dynamics dictate the need to adapt existing models to address the complex socio-economic and institutional realities within the Nigerian context. Combining ownership models and financing mechanisms provides a critical pathway towards effectively scaling CRE initiatives and combatting energy poverty in Nigeria. Therefore, while Germany and Denmark offer important lessons for Nigeria's energy

transition, context-specific dynamics dictate the need to adapt existing models to address the complex socio-economic and institutional realities within the Nigerian context.

Community-owned and cooperative models, underpinned by government grants, revolving funds, and climate finance mechanisms, provide a foundation for fostering local participation and ownership. Collaborating with private sector investors through PPPs and leveraging tools like PAYG systems further ensures financial inclusivity and scalability. Moreover, Nigeria's decentralized energy governance framework must integrate these models with robust regulatory support and capacity-building initiatives.

By aligning local and national priorities through green bonds and climate funds, CRE projects can contribute to Nigeria's Nationally Determined Contributions (NDCs), addressing both energy poverty and climate goals. Ultimately, ownership and financing models are more than operational strategies—they are vehicles for ensuring the social, economic, and environmental sustainability of CRE initiatives. By adopting a tailored, hybrid approach that reflects Nigeria's unique socioeconomic realities (see Section 5), the country can advance toward equitable energy access and inclusive energy transitions.

2.5 Energy Policy Issues and Challenges in Nigeria

Despite global advancements, an estimated 573 million people in SSA lack access to electricity, equivalent to around 41% of the population [152] [9]. Nigeria, the sixth most populous nation in the world, with an estimated 219 million citizens [153], is energy deficient, unable to meet the need of its rising population and facing a significant energy crisis despite its abundant RE potential [2,109,154,155]. Although Nigeria relies heavily on fossil fuels to support its energy infrastructure, there is a significant shortfall in satisfying the increasing energy demands of a growing population [2]. Foremost, the national electrification rate in the country stands at approximately 55%, with rural electrification at around 39% [156]. The persistent growth of Nigeria's annual CO₂ emissions further compounds this predicament (see Supplementary Materials, Figures SM1–SM3).

In rural communities, access to energy is even more limited, with the average household consuming only 100 kWh of electricity, which is significantly less than 4500 kWh, 1934 kWh, and 1379 kWh consumed in South Africa, Brazil, and China respectively [157]. This

shortage forces families and businesses to rely on portable hydrocarbon-powered generators to supplement energy needs [155,158]. CRE adoption in Nigeria is overdue given rising energy demands and substantial citizen investments in hydrocarbon-powered generators. Introducing CRE can create a cleaner, more reliable energy market while raising awareness about RE's role in sustainability, rural development, lower health costs, energy independence, and economic growth [157]. Specifically, the northern region, with the highest lack of access to electricity, stands to benefit significantly from CRE adoption, as depicted in Fig. 2-2.

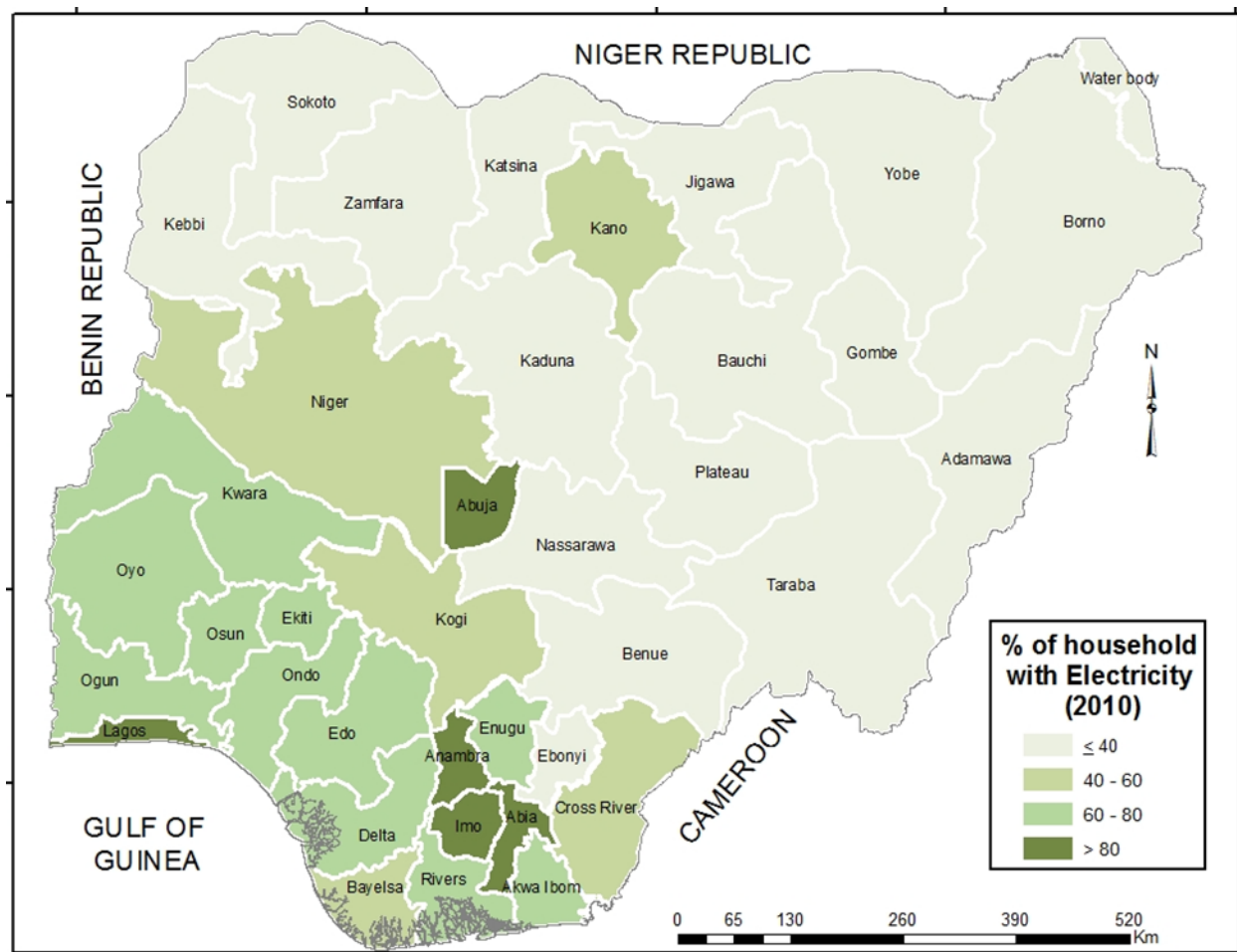


Figure 2-2. Spatial distribution of households with electricity in Nigeria.

Source: [159].

2.5.1 Energy Policy Developments in Nigeria

Diversifying Nigeria's energy supply with renewables is imperative amid global concerns about climate change, the environment, and sustainable development [160,161]. In response, Nigeria has implemented energy policies, programs, and legislation to enhance accessibility, however, progress to date has fallen short of realizing economic ambitions. In this study, energy policy pertains to government strategies for boosting energy production, decreasing emissions, and improved efficiency [162]. Table A1 provides an overview of Nigeria's energy policies and Acts for both renewable and non-renewable sources to further contextualize the focus of this analysis.

Despite degrees of policy changes, institutional restructuring, persistent challenges in Nigeria's energy landscape (see Supplementary Materials, Table SM1), the country still falls short of its energy sufficiency and RE targets. The revised Renewable Energy Master Plan (REMP) 2012 aimed for 23% RE by 2025, but by 2023, only 4% was achieved. As of December 2022, RE targets remain unmet. Similarly, RESIP's goal of nationwide electricity access had limited success. While the Electricity Act of 2023 represents a significant step forward in Nigeria's energy legislation, it falls short of the objectives outlined in the CRE-MLG framework due to certain limitations.

Section 2(2) of the Act grants authority to states, companies, and individuals for electricity generation, transmission, and distribution, but excludes roles for local government authorities, citizens, and communities. Additionally, the Act lacks provisions for energy storage, which are crucial for maximizing the potential of RE within the energy mix. Despite its passage, the law faces challenges, as most governors have yet to adopt it, and the Nigerian Electricity Regulatory Commission (NERC) has approved a substantial 300% increase in electricity tariffs, exacerbating the already unreliable power supply [163]. With 46 grid collapses between 2017 and 2023, Nigeria continues to grapple with frequent power failures, leading to widespread reliance on small carbon powered backup generators which provide 40% of the total electricity [164].

Although, various policy revisions aiming at RE goals over the years, none of these revisions present a comprehensive strategy for CRE across all local communities in Nigeria, including the recent Nigerian Electricity Act 2023 [165]. This Act empowers state

governments but overlooks citizens and local governments (see Table A1). The absence of roles assigned to local governments hinders aspirations for developing and accelerating decentralized RE. Consequently, there is a pressing need to prioritize citizen engagement and social acceptance through supportive frameworks targeting a low-carbon and inclusive energy future [166]. This resonates with Petersen's [141] observation regarding an implementation gap between national policy and local practice as a barrier to meeting RE targets. In sum, the Nigerian Electricity Act of 2023 falls short of taking a transformative approach towards decarbonization, as it primarily focuses on modernizing and expanding traditional energy infrastructure without prioritizing citizen engagement in its policies.

2.5.2 Implications of Community Renewable Energy in Nigeria

Climate change dimension

Current estimates suggest the Paris Agreement's 2°C target will fall short without global investments of around \$1 trillion in RE [152]. RE adoption is imperative for securing rapid shifts in energy efficiency and electrification to reduce GHG emissions [87,167,168]. Nigeria faces challenges like fossil fuel reliance, carbon lock-in, and limited government support for RE. Despite the urgent need for a low-carbon shift, not all countries fully endorse or meaningfully support the RE transition [87,100,169]. Counteracting a low-carbon trajectory, Nigeria subsidizes imported refined hydrocarbon fuels [154]. Implementing initiatives like CRE could redirect subsidy funds towards vital areas like healthcare, education, and transportation.

Government budget constraints and socioeconomic impact

Given the substantial investments by governments and multinational entities in global energy transition, there is a growing call for the involvement of individuals and civil society actors [127]. In the UK context, Mirzania et al. [170] argue that strategic support for enhancing networking and collaborative efforts through citizen participation could bolster CRE initiatives during the energy transition, thereby mitigating investment risks and market constraints. Furthermore, the adoption of CRE with government backing in rural areas holds the potential for substantial socioeconomic advantages, including improved

education, healthcare, access to safe drinking water, empowerment of women and youth, and poverty reduction [171].

Seasonal variations and energy security dimension

Declining dam water levels contribute towards energy instability coupled to grid dependence highlighting the need for a more decentralized energy system in Nigeria [157]. To address these challenges, Ikejemba et al. [172] propose CRE solutions for decentralizing energy production. Furthermore, Bauwens [169] highlights energy security threats in SSA stemming from limited fossil fuels, price volatility, and energy poverty. Similarly, Süsser and Kannen [87] emphasize the growing recognition of RE for low-carbon, sustainable, and secure nations, in alignment to the Paris Agreement.

2.6 Two types of multi-level governance

Hooghe and Marks [28] proposed two classic ideal models of MLG: Type I and Type II (see Table 2-4). Type I is common in federal systems where the central government shares power with multiple levels of government, resulting in a flexible and adaptable administration with limited interactions among jurisdictional levels [173,174]. Type II MLG is more versatile, spanning multiple levels with overlapping jurisdictions, involving government agencies, state-owned enterprises, industry groups, and non-governmental organizations (NGOs) to address specific tasks or policies. Accordingly, Type I is characterized by state-centric politics, while Type II features task-specific jurisdictions, flexibility, and adaptability to transient needs [25], whereby the operational character of institutions is brought to life by actors at various government levels [175].

Table 2-4. Type I and Type II Multi-level governance.

Table of Contents	Type II
• General Purpose jurisdiction	• Task-specific jurisdictions
• Non-intersecting memberships	• Intersecting memberships
• Jurisdictions organized on a limited number of levels	• No limit to the number of jurisdictional levels
• System-wide architecture	• Flexible design

Source: Adapted from [28]

2.6.1 Type I Multi-level Governance: Jurisdictional Governance

Type I MLG limits authority dissemination to a few non-overlapping jurisdictional borders across a limited number of levels, emphasizing stability and government levels rather than specific programs [176]. In contrast, Type II MLG views governance as a complex and fluid system with overlapping governments, organized around tasks and adaptable to changing governance needs [174], as conveyed in Table 1-4.

Gargano [43] characterizes Type I MLG as a general-purpose jurisdiction across international, national, regional, and local levels, divided into units with distinct authorities and policy requirements. It typically includes executive, elected legislature, and judiciary structures, with municipalities serving as stable entities overseeing various aspects of governance. These structures align with the formal, federalist qualities of Type I MLG, which feature hierarchical jurisdictions to some extent [177].

Type I MLG operates with well-organized, layered roles across multifunctional organizations and networks at defined levels. Type I MLG emphasizes finite levels of collaboration or cooperation, which Zürn [178] refers to as cooperative federalism in modern states. Conversely, Type II MLG exhibits more flexible institutional frameworks allowing for membership overlap between levels [24]. While Type I serves as the formal implementation framework, the mechanisms of Type II MLG can either support or hinder policy implementation [177].

2.6.2 Type II Multi-level Governance: Distributed Public Governance

Type II MLG delegates implementation responsibilities to government bodies with non-overlapping geographical jurisdictions, emphasizing task-specific, single-purpose entities across various governmental levels and independent of ministerial agencies [177]. This approach transcends hierarchical tiers and offers a more fluid analysis across geographical and jurisdictional boundaries [23]. CRE projects align with this approach, as local planners follow national and regional policies [27].

Gargano [43] further distinguishes Type II MLG as task-oriented and adaptable to changing functional needs. It involves specialized public services such as law enforcement, fire protection, social services, and transportation, each with its internalized jurisdiction. This category involves various public and private actors coexisting in the

same space and addressing coordination challenges collectively at the relevant level. Type II MLG is associated with economic efficiency, adaptability, innovation, community engagement, and shared decision-making [43].

Drawing from MLG theory, both Type I (jurisdictional governance) and Type II (distributed public governance) are conceptually relevant to Nigeria's decentralized energy landscape. Jurisdictional governance, characterized by vertical power distribution, poses challenges in addressing localized policy needs due to centralization. In contrast, distributed public governance, focuses on horizontal coordination and involving various stakeholders, offers opportunities for collaboration and inclusive policy development. Nigeria can benefit from integrating both approaches, leveraging the federal government's role while strengthening collaboration across government levels and with non-state actors to enhance policy outcomes and sustainable development.

2.6.3 The multi-level governance approach in Germany and Denmark

The analysis of Germany and Denmark's RE strategies through the MLG framework reveals distinct approaches to CRE development. Germany's model aligns with Type I MLG, featuring top-down policy formulation at the national level, complemented by decentralized governance structures empowering local communities to drive CRE initiatives. Denmark, on the other hand, embodies Type II MLG, characterized by task-specific jurisdictions and collaborative efforts among diverse stakeholders to address specific policy objectives. Both countries showcase how MLG principles shape CRE outcomes, emphasizing the importance of coordination, collaboration, and decentralization in achieving sustainable energy transitions.

The aim of using the two western cases is limited to drawing empirical examples of citizens' mobilization, engagement, and participation in the RE transition. However, CRE in the western context does not necessarily fight energy poverty. In a SSA country like Nigeria, subsistence energy has the potential to alleviate energy poverty in a straightforward manner. By transitioning from carbon-powered generators to clean and sustainable energy sources, small and medium enterprises (SMEs), which drive local economies, can significantly reduce their operational costs, thereby enhancing their ability to thrive.

2.7 Conceptual framework

The success and public acceptance of RE initiatives, including community-based projects like CRE, depend significantly on the implementation strategy [74]. This underscores the need to customise policies to fit the local context. MLG can play a pivotal role in shaping a context-specific CRE policy framework for Nigeria. Such a framework would align with the nation's unique political, social, and cultural dynamics, addressing shortcomings in previous government-led approaches. In response, the proposed CRE-MLG framework (see Fig. 2-3) provides a viable alternative for supporting Nigeria's potential transition to a low-carbon economy. By engaging local citizens in energy production and adopting a community-based approach, CRE-MLG aims to foster sustainable and reliable energy solutions through a decentralized approach.

CRE-MLG, as conceptualized in Figure 2-3, could prove instrumental to supporting a clean and equitable energy future in Nigeria. Past energy policies, (See Appendix SM1) have fallen short of achieving stated targets, while failing to combat energy poverty. This shortcoming stems from the federal government's exclusion of local governments and communities from energy policy formulation and coordination. To date, a focus on centralized energy policies and regulations has yielded limited results. Moving forward, local governments — though not fiscally autonomous — can serve as effective operational hubs for implementing CRE initiatives, given their proximity to communities and their role in existing federal programmes like Universal Basic Education Commission (UBEC) and Primary Health Care (PHCs). Shifting the focus to MLG can foster a more democratic and legitimate public policy development process, help decentralize state power and encourage a more pluralistic administration by involving local governments, non-state actors, and community stakeholders. This approach holds promise for CRE advancement in Nigeria, considering the country's diversity and vast size.

The CRE-MLG framework offers a solution by engaging state (mid-level) governments, local governments, and communities as pivotal players in CRE development, alongside the federal government. In Nigeria, the existing 776 local governments are particularly well-positioned to interact with communities, underscoring the significance of collaboration among national, regional (36 states), and local stakeholders. Each

government level has distinct jurisdictional roles and responsibilities, necessitating synergies between state and non-state actors for effective implementation. As depicted in Figure 2-3, promoting CRE is predicated on harnessing potential synergies between top-down and bottom-up processes.

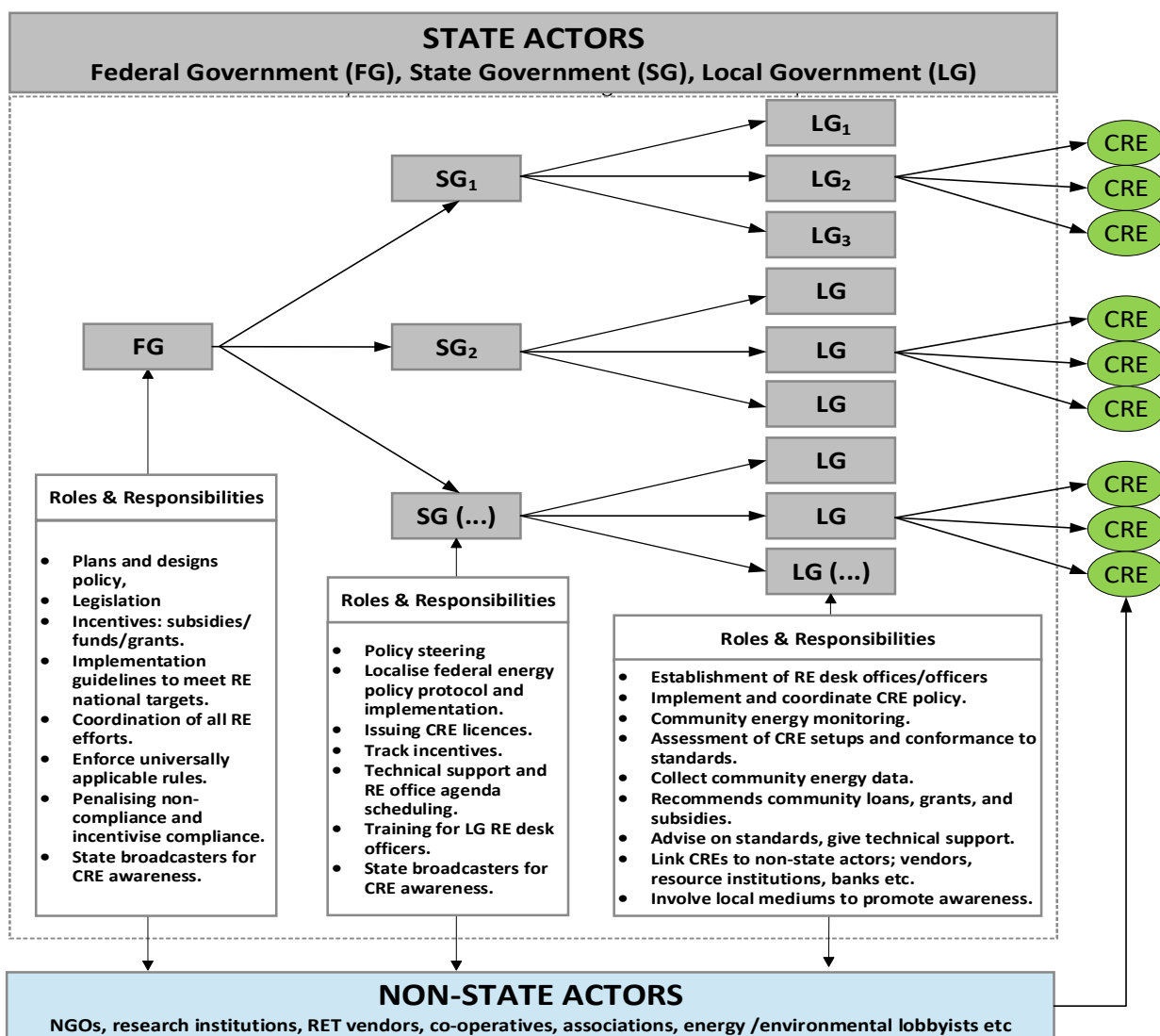


Figure 2-3. The Community Renewable Energy Multi-Level Governance conceptual framework

2.7.1 Roles of key actors supporting CRE-MLG

Given the importance of energy as a national resource in a SSA nations such as Nigeria [179], under the CRE-MLG framework, it is crucial for state actors at all three tiers to

collaborate with non-state actors. Currently, critical institutions in Nigeria's energy industry are centralized and concentrated at the federal level. In Table 1-2, it is noteworthy that in the Danish case, part 1 (3) of the promotion of RE Act (2009), clearly stipulates and includes roles of actors in municipalities in the national transition plan [139]. Therefore, the framework aims to address this by decentralizing roles and responsibilities to lower levels of government to promote RE penetration in the country.

Implementing CRE-MLG is the responsibility of key actors at both vertical (state) and horizontal (non-state) levels. Figure 2-3 highlights the three state actors representing the federal, state, and local governments vertically, while non-state actors are horizontally juxtaposed to the framework at each level of authority including the local community who are host to where RE initiatives are domiciled. These non-state actors provide technical support and input to governments and act as private sector partners in crystallizing the CRE-MLG approach. While the federal government is the highest coordinating entity at the top, the state governments (mid-level) government follows and then local government (bottom level) which is closest government to the community (non-state) actors, who host the CRE project.

2.7.2 State actors

Federal Government

The Federal government (FG) plans and designs CRE policy framework, legislates, support with funds/grants, and creates CRE implementation guidelines to meet national RE targets. Following the tenets of the CRE-MLG framework, the federal government is primarily tasked with coordinating all RE efforts and enforcing universally applicable rules by penalizing non-compliance, while incentivizing compliance. The FG also has the responsibility of using its broadcast institutions for CRE public awareness campaigns.

State Government

The state government (SG), composed of the 36 states of Nigeria, carries out governance at the meso-level (mid-level). The proposed framework suggests scaling down federal energy policy guidelines and implementation protocol to fit local contexts, thus accounting for diverging cultural and social characteristics across states. The main responsibility of

the SG includes policy steering, issuing CRE licenses, maintaining a record of funding, coordination and agenda setting for RE offices and technical support/ training for local government renewable energy desk officers (REDOs). As a pivotal link in the CRE-MLG chain, REDOs correspond to focal officials in local government (LG) offices responsible for implementing and coordinating national CRE policy objectives.

Similar to the FG, SGs can use their broadcast institutions for CRE public awareness campaigns. The new Electricity Act of 2023 [165] grants SGs authority over power generation, transmission, and distribution within their respective states. Notably, section 63(1) of the Act acknowledges the unique needs and objectives of each Nigerian state, encouraging the enactment of state-level legislation related to the electricity industry. This provision allows SGs to tailor laws and policies to suit their specific requirements, promoting a decentralized approach to the development of the electricity sector in Nigeria. Furthermore, the Act acknowledges the SGs' authority to issue licenses for activities related to electricity markets within their states. Coincidentally, this is the juncture at which the new electricity Act ceases, restricting the involvement and accountability of the pivotal and most proximate tier of government to the populace and consumers of this energy, namely, the local government.

Local government

The local government (LG) is more accountable for understanding and implementing national RE policy since it can more easily engage at the community level [81], thereby strengthening prospects for 'connecting power to people'. The LG sits at the lowest level in the vertical element of the CRE-MLG framework yet carries the most weight in terms of its roles and responsibilities. It is crucial to highlight that none of Nigeria's 774 local government areas (LGAs) currently has an agency or a staff devoted to energy programmes, projects, or challenges. This stands in contraction to other Type I governance institutions such as health and education, which have departments and staff domiciled in all LGAs in the country.

To ensure effective implementation at the local level, the framework proposes the appointment of Renewable Energy Desk Officers (REDOs) at each of Nigeria's 774 local government areas (LGAs), drawing on models already established in the health,

agriculture, and education sectors. A core team of three REDOs per LGA—totaling approximately 2,322 officers nationally—is proposed. This recommendation reflects existing precedents in decentralized service delivery, such as Primary Health Care Coordinators, Agricultural Extension Officers, and Education Desk Officers, who currently operate at scale across Nigeria’s LGAs.

Rather than functioning as high-level bureaucrats, REDOs are envisioned as mid-level technical facilitators who coordinate renewable energy activities, monitor community-level adoption, support private sector engagement, and link federal policy to local implementation. While this staffing model is aspirational, it is also grounded in precedent and should be viewed as an adaptive policy mechanism—scalable based on institutional readiness, local needs, and available resources. The objective is not to create additional bureaucratic burden but to address a persistent operational gap that has hindered Nigeria’s energy transition from effectively reaching the grassroots.

In contrast, the Danish case presents an example where there is a strong connection between national RE targets, community acceptance, participation, and local policy implementation [92,141]. In 1977, the Danes established the federation of local energy offices (SEK) with staff in all municipalities (local authorities) to help ensure collaboration and participation of residents in meeting national goals [140]. With step down training from SGs, REDOs assess CRE setups, architectures, and conformance according to standards and collect accurate energy data in the community. This SG level connects federal RE policy to local communities where CRE operates establishing a bottom-up channel. It also can approve federal community loans, grants, and subsidies.

LGs are responsible to advise communities on sustainability standards, give technical support, and connect them to non-state enterprises including RE manufacturers, vendors, resource institutions and banks [137]. LGs also have the responsibility of using local mediums, outreaches, associations, traditional / religious leaders for CRE public awareness campaigns.

2.7.4 Non-state actors

The framework presented in Figure 2-3 incorporates various non-state (private) actors within its horizontal governance structure and their involvement is crucial across all tiers

of government [118]. These actors play a significant role contributing towards national level where policies are formulated, as well as the local level where government programs are implemented and executed in collaboration with each level of government, either independently or in a complementary manner. While the objectives of non-state (private) may extend beyond profit-making, encompassing endeavors such as addressing climate change concerns, ensuring energy security for vulnerable populations, and protecting the environment, their identities encompass a wide range of entities. These actors include private developers, RET vendors, international and national consultants, civil society organizations/non-governmental organizations, financial institutions, political and environmental advocacy groups, research institutions, prosumers (producer-consumers), academia, training companies, voluntary associations, pressure groups, professional organizations, among others.

2.7.5 Community-level actors

Given the absence of a singular trajectory towards achieving a low-carbon transition within any particular nation, the conventional elucidation of identifying appropriate stakeholders in CRE is contingent upon the interests of constituents and policymakers. It is crucial for actors responsible for determining the parameters of CRE to make well-informed and deliberate choices, as these decisions have ramifications on the scalability, management, funding, establishment, and regulation of CRE initiatives, thereby significantly impacting the parties affected by the outcomes [83].

The effective implementation of CRE necessitates the active involvement of the community actors in the processes of planning, decision-making, and administration through establishing and legalization of unstructured energy associations and cooperatives. This is to ensure the successful operation of a CRE project within a community, the CRE-MLG framework proposes engaging and collaborating with key community actors, leaders including residents and local institutions as key stakeholders. By incorporating their perspectives, obtaining their acceptance, leveraging on their indigenous knowledge, securing their endorsement and encouraging their participation, these actors assume the role of project stewards, fostering a sense of ownership and commitment towards the project within their community.

2.7.6 The value proposition of CRE-MLG

Decentralization in Nigeria has already been applied across key sectors such as education, healthcare, agriculture, and water supply. For instance, the Federal Government devolved educational responsibilities to state governments, while primary education delivery falls under the jurisdiction of local governments. Although service delivery in these sectors continues to face systemic challenges, decentralized structures remain critical conduits for reaching underserved populations. These limitations, however, do not diminish the institutional relevance of decentralized systems. Rather, they underscore the importance of context-specific design and the need for continuous refinement of implementation models. The CRE–MLG framework proposed in this thesis does not idealize decentralization; instead, it builds on these precedents—not by replicating their shortcomings, but by learning from them. It introduces targeted, renewable energy-specific interventions that leverage grassroots participation. Central to this is the introduction of Renewable Energy Desk Officers (REDOs), envisioned as locally embedded agents to enhance coordination, accountability, and community-level adaptation. Ultimately, scientific and policy innovation are not driven by certainty but by iterative experimentation—through which new insights emerge, systems evolve, and transformative change becomes possible.

A successful model that can be adopted and modified in Nigeria is the Universal Basic Education Commission (UBEC) for primary education at local government level. UBEC is backed by the Universal Basic Education Act (2004) which mandates the provision of basic education in Nigeria. It was established to oversee the programme's implementation at the state and local levels. This coordination occurs through the State Universal Basic Education Boards (SUBEB) in each state and the Local Government Education Authorities (LGEAs) [180,181]. With the CRE-MLG framework, REDOs at the LG level would function as the primary contact points for 'bottom-up' RE development and coordination within communities. They would engage with community stakeholders and residents, oversee off-grid associations or cooperatives, provide information on accessing quality RETs, facilitate access to government subsidies and ensure the dissemination of government's national sustainability goals.

The Afrocentric CRE model differs from European frameworks by focusing on decentralized, subsistence-level energy provision for households and small enterprises, emphasizing community involvement. Financing this model through the supervision of REDOs, would rely on a combination of government subsidies, international aid, micro-financing, and private-public partnerships, with additional support from grants and climate funds. The community plays an active role as "prosumers," participating in decision-making, governance, and management to ensure sustainability. While not profit-focused, cost-recovery mechanisms such as affordable tariffs would ensure long-term viability by covering operational expenses. Ultimately, the Afrocentric CRE model prioritizes social and economic benefits for the community, fostering local resilience and energy autonomy.

Considering the spending of Nigerian citizens on hydrocarbon-powered generators [12], through harnessing local resources and community involvement, CRE can provide reliable and clean energy for domestic use, small-scale businesses, and community facilities. Collaboration between government, private sector, and civil society stakeholders is crucial to support and scale up CRE initiatives, facilitating Nigeria's transition towards a resilient and low-carbon energy system. However, the CRE-MLG framework offers a solution to accelerate Nigeria's transition to a low-carbon economy and support the fulfilment of our Nationally Determined Contributions (NDCs) to the global economy.

2.8 Conclusion

To date, few studies have examined the socio-political dynamics of CRE projects and how they address energy inequalities in developing countries like Nigeria [182]. Despite the growing prevalence of CRE initiatives, research on their effects and contributing factors is mostly concentrated in Europe and North America, with scarce attention given to the implementation of programs in developing nations in SSA [183].

This study marks a novel contribution to the socio-technical transitions literature in the global south by integrating CRE and MLG into a conceptual framework, with a specific focus on the potential for developing CRE initiatives in Nigeria. The entry point to the analysis involved analyzing the characteristics, constraints, mobilization strategies, and state facilitation of CRE in Germany and Denmark to identify potential success factors for

adopting in the Nigerian context. Using the CRE-MLG framework, the study assesses the viability of CRE efforts in Nigerian communities to address energy poverty. The findings of this study may inform the development of a policy framework that promotes CRE activities and enables REDOs at the local government level to effectively oversee and monitor policy targets and access to energy infrastructure. Additionally, the CRE-MLG framework offers a solution to accelerate Nigeria's transition to a low-carbon economy and support the fulfilment of our Nationally Determined Contributions (NDC) to the global economy.

The novelty of this study lies in its integration of two key concepts: CRE and MLG. This approach recognizes the importance of community involvement and decentralized decision-making in RE development, while also acknowledging the complex interplay of governance structures at multiple levels. By combining these perspectives, the framework offers a holistic understanding of how CRE initiatives can be effectively implemented within the context of diverse and tiered governance systems. Scholarly innovation is evident in the framework's emphasis on critical learning points derived from empirical research and theoretical insights. Through rigorous analysis of two case studies, existing literature, and policy documents, key lessons emerge regarding the role of stakeholders, the effectiveness of governance mechanisms, and the challenges and opportunities inherent in CRE implementation. These critical learning points are identified through review of literature and synthesis of evidence and highlighting best practices.

A more critical assessment of the transferability of these learning points to the Nigerian context is essential. While the CRE-MLG framework offers valuable insights into effective RE governance, its applicability to Nigeria may be limited by contextual factors such as political dynamics, institutional capacity, and socio-economic conditions. Critical scrutiny is needed to evaluate the feasibility and adaptability of CRE-MLG principles within Nigeria's unique governance landscape. This assessment should consider the alignment of the framework with existing policies and practices, the potential for stakeholder buy-in and participation and the scalability of CRE initiatives across diverse communities. Additionally, attention must be paid to potential barriers and challenges, such as regulatory constraints, funding limitations, and socio-cultural norms, which may impede

the implementation of CRE-MLG strategies in Nigeria. Overall, a nuanced and context-specific analysis is necessary to assess the potential impact and feasibility of adopting the CRE-MLG framework in the Nigerian context.

2.8.1 Implications for policy makers

Without the Danish government's systematic and deliberate public policy intervention in the market, its wind power technology would not be the global success it is today [68,139]. Therefore, CRE through this MLG-CRE framework would not spread without institutional support, such as a supportive energy policy by the Nigerian government or political class [82,92]. Without focused government policy, the implementation of CRE in Nigeria may occur in a disparate, uncoordinated, and unsystematic manner. And implementation success rates are directly proportional to local acceptance levels [19]. Decentralization creates institutional space for local (community) actors, which is essential to institutional progress [18]. However, the Nigerian government lack supportive policy schemes for CRE, so policymakers may want to maximize the potential of community investment in CRE by designing effective policies with multiplier effect on local communities in Nigeria, such as combating energy poverty, reducing the country's carbon footprint, improving quality of life, and promoting economic growth [98].

Echoing Ohunakin's [184] call to develop favorable policies and strong "political will" at all levels of government (federal, state, and local) in Nigeria to accelerate RE development. For CRE-MLG to take root in Nigeria, appropriate policies must a) effectively unbundle and distribute the intricate and overloaded monopoly of energy administration held solely by the FG. This entails delegating well-defined roles and responsibilities to the other two tiers of government, as depicted in Figure 2-3, fostering an interdependent yet collaborative structure b) consider citizens as a source of funding for the energy transformation, c) prioritize public engagement as the key to a successful energy transformation, especially given the substantial impact on energy use by citizens, and d) enhance the local energy industry administration through offices of REDOs so that residents and local stakeholders can engage in RE initiatives.

2.8.2 Limitation of research

A limitation of this study lies in the use of a narrative literature review, which can introduce selection bias in choosing sources and references, potentially leading to gaps in coverage. Unlike systematic reviews, which follow a structured and transparent methodology, narrative reviews may unintentionally prioritize certain perspectives or omit relevant studies. To address this, future research should consider adopting a systematic review or meta-analysis to provide a more comprehensive and objective synthesis of the literature on CRE in SSA, which is currently lacking in the field.

2.8.3 Further research agenda

The liberalization of the energy sector has been an ongoing policy initiative in many SSA countries. In this context, the CRE-MLG framework has been proposed as a useful tool to guide energy sector reforms in the region. However, there is a need for further research to explore the implementation of this framework, particularly in terms of defining stakeholder groups and customizing CRE structures for local environments in SSA. This would involve adapting the CRE-MLG framework to suit the specific institutional, legal, and socio-economic contexts of individual countries in the region. Such customization would be essential to ensure that the framework is effective in achieving its intended objectives in different settings.

Another critical area of further research could focus on the identification and classification of stakeholder groups in the energy sector in SSA countries. This would involve a thorough analysis of the various state and non-state actors involved in the sector, including government entities, private companies, civil society groups, and individual consumers. Such an analysis would provide a clearer understanding of the interests and priorities of these groups and could inform the development of tailored policy interventions.

Unlike Germany and Denmark, which have experienced RE expansion facilitated by their stable political history, Nigeria's history of political volatility has hindered similar progress. This instability has impeded critical factors necessary for the advancement of CRE research within the country, such as inadequate funding, difficulty in conducting in-depth studies and limited access to reliable energy utilization data, particularly in rural areas.

These constraints complicate the development of community-scale RETs and the design of RE systems tailored to local energy needs. Furthermore, as highlighted in the policy documents reviewed, Nigeria lacks a cohesive regulatory framework for CRE initiatives, resulting in ambiguity and making it difficult for researchers to access clear, consistent information on CRE efforts.

Future research should involve adapting the CRE-MLG framework to suit the specific institutional, legal, and socio-economic contexts of individual countries in the region and a review of various LG/citizens ownership models. Overall, further research in these areas could inform the development of evidence-based policy interventions to promote sustainable and inclusive energy access and economic growth in Nigeria.

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Supplementary Materials to Chapter 2

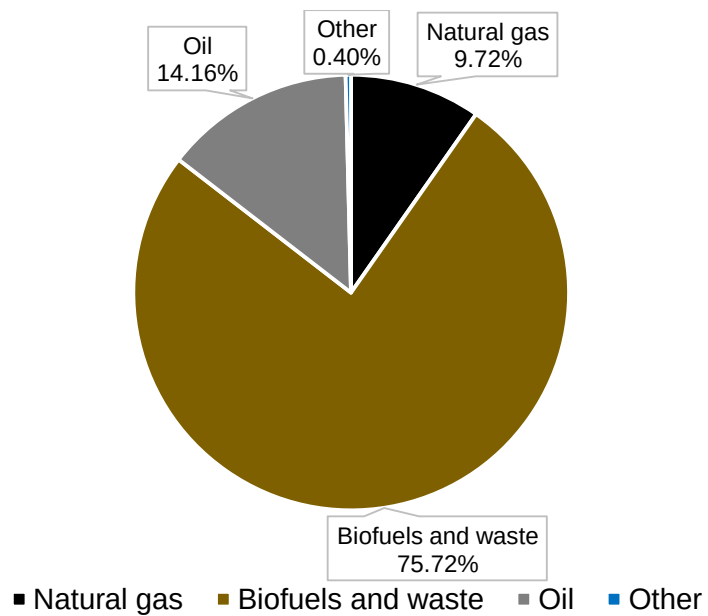


Fig. SM1. Distribution of energy sources in Nigeria in 2020.

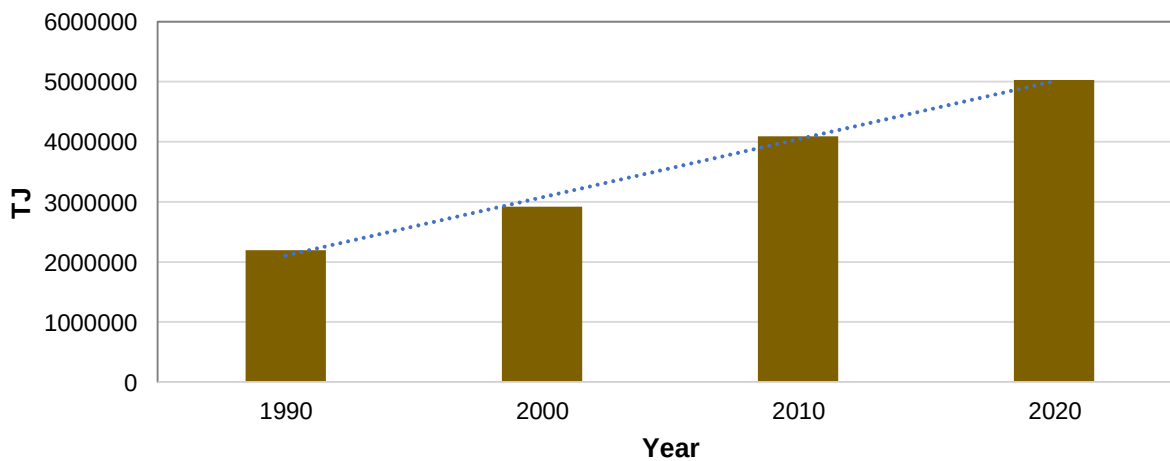


Fig. SM2. Energy supply from biofuels and waste, 1990–2020.

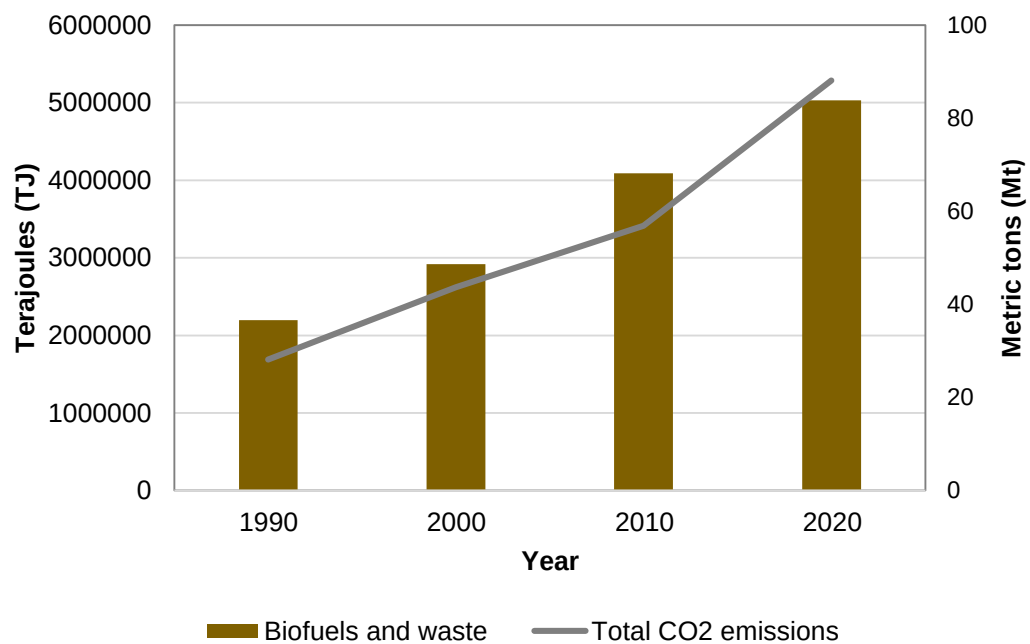


Fig. SM3. Trends in Nigerian energy consumption and CO² emissions, 1990–2020 [185].

Table SM1. Summary of Nigeria's energy policies to date.

Policy	Start year	Key details and characterization	Source(s)
National Electric Power Implementation Policy (NEPIP)	2001	<ul style="list-style-type: none"> Unbundled the powerful state-owned NEPA into electricity-generating Independent Power Producers (IPPs) to boost market competitiveness, phase out subsidies and sell excess electricity to Distribution Companies (DISCOs) for full market liberalization. No focus on renewable energy 	[186], [4]
National Energy Policy (NEP) 2003, (Reviewed 2006, 2013)	2003	<ul style="list-style-type: none"> Addressed energy production, supply and consumption. Promoting rapid solar energy integration into Nigeria's power system and efficient use of other RES to diversify energy sources and ensure energy security. 	[186], [155]
National Economic Empowerment and Development Strategy (NEEDS)	2004	<ul style="list-style-type: none"> Supported a higher RE balance. Proposed a RE agency and National Power Sector Reform Act-sponsored technology 	[186]
National Power Sector Reform Act -NPSRA	2005	<ul style="list-style-type: none"> Liberalized Nigeria's power sector in response to the 2001 NEPIP's new legislative and regulatory framework. Unbundled and privatised the electricity sector Restricts licensee rights to the federal government to manage the deregulated energy market Facilitated the establishment of National electric regulation commission (NERC) and the Rural Electrification Agency (REA) 	[186], [187], [155]
Renewable Electricity Policy Guidelines (REPG)	2006	<ul style="list-style-type: none"> Expanded RE generation targets (5% of total power generation by 2025 and 5 TWh) Defined RE development usage and policy aims, prioritizing RE production and distribution Proposed cost-effective RE trust fund management. 	[186]
Renewable Electricity Action Programme (REAP)	2006	<ul style="list-style-type: none"> Cleared the playing field for RE providers, multi-sector alliances, demonstration projects and supply chain activities Investigated RE programme support. 	[186]

Nigerian Biofuel Policy and Incentives (NBPI)	2007	<ul style="list-style-type: none"> • Integrate agricultural activities with oil and gas activities • Aimed to grow and promote the domestic fuel ethanol sector by using agricultural goods, gradually reduce the nation's reliance on imported gasoline, reduce environmental pollution and develop financially viable businesses and sustainable jobs 	[186] [155]
Multi-Year Tariff Order (MYTO) 2008 & 2012	2008	<ul style="list-style-type: none"> • The NERC created MYTO 1 in 2008 to cost-reflective pricing. Then MYTO II (2012-2017) • MYTO determines reasonable prices for licensed energy producers to provide distribution and retailing enterprises under the EPSRA (2005) Act • No focus on renewable energy 	[188]
Renewable Energy Master Plan (REMP) 2005, (Revised) 2012	2012	<ul style="list-style-type: none"> • Based on an increasing convergence of goals, concepts and aims of NEEDS, National Energy Policy, National Policy on Integrated Rural Development, Millennium Development Goals (MDGs) and international treaties to alleviate poverty and reverse global environmental change • Promoted building grid, and off-grid RE integration, underlining the importance of solar energy • Expected growth of RE generation from 13% in 2015 to 23% in 2025 and 36% by 2030 • REMP expects 10% of Nigeria's electricity to be renewable by 2025. 	[186] [155]
National Renewable Energy and Energy Efficiency Policy	2015	<ul style="list-style-type: none"> • Prioritized hydropower, biomass, solar, wind, geothermal, wave, tidal, co-generation, and energy efficiency • Meant to be driven by community-funded RE systems. Established the National Energy Efficiency Action Plans 2015–2030 (NEEAP)/National Renewable Energy Action Plans (NREAP). 	[155]
Rural Electrification Strategy and Implementation Plan (RESIP)	2017	<ul style="list-style-type: none"> • Supported the REA to increase energy availability quickly and cheaply • Demanding widespread adoption of grid and off-grid alternatives and access-based incentives • Outlined the Nigerian rural electrification enabling framework. 	154], [157]
The Nigeria Electrification Project	2018	<ul style="list-style-type: none"> • Nigeria's most ambitious energy project yet with an estimated \$1.215 billion portfolio investment. 	[189]

		<ul style="list-style-type: none"> • Breakdown: African Development Bank (AfDB)—\$150 million (loan), Africa Growing Together Fund (AGTF)—\$50 million, World Bank—\$350 million, Government of Nigeria—\$5 million (counterpart funding), Others (Private Sector)—\$660 million (commercial financing). • Policy goals: (i) 60% rural power by 2020 and RE as rural development accelerator. Low-cost equipment and operators. (ii) the government intends to improve energy access to rural and underserved areas and deliver at least 10,000 MW (off-grid and on-grid) of operational capacity by 2020 	
Climate Change Bill	2021	<ul style="list-style-type: none"> • Incorporated RE strategies for Nigeria's net-zero aim for 2050–2070 and five-year carbon budgets under a National Climate Change Action Plan • The Federal Ministry of Environment sets the carbon budgets and the National Council on Climate Change implements them 	[190], [191]
Nigeria Electricity Act,	2023	<ul style="list-style-type: none"> • The Act repeals and replaces the Electricity and Power Sector Reform Act of 2005 and aims to establish a decentralized legal and institutional framework for Nigeria's power sector, covering electricity generation, transmission, distribution, and supply, as well as fostering the integration of RE into the country's energy mix • Aims to facilitate an environment conducive to investment in the Nigerian Electricity Supply Industry (NESI) 	[165]

3 EVALUATING DETERMINANTS OF COMMUNITY RENEWABLE ENERGY DEVELOPMENT IN NIGERIA: INSIGHTS INTO SUSTAINABLE ENERGY TRANSITIONS IN SUB-SAHARAN AFRICA⁶

**Kim Del Kaze, Nazmiye Balta-Ozkan, Elisabeth Shrimpton, Julide Yildirim*

Abstract

Access to reliable and affordable energy remains a pressing challenge in Sub-Saharan Africa, with Northern Nigeria illustrating the depth of the gap. Community renewable energy (CRE) offers a pathway to address supply deficits and local participation, yet evidence on how socioeconomic and informational factors shape household commitment is limited. Using survey data from 559 households across six states, we estimate a multinomial logit model with interaction terms to examine determinants of CRE adoption. Beyond affordability and infrastructure, results highlight the layered influence of income, awareness, and education, with occupation and household size exerting secondary effects. Interaction terms show that informational access (awareness) conditions socioeconomic constraints by amplifying or offsetting disadvantages, underscoring awareness as a low cost and high impact policy lever. Two implications follow: subsidy-based interventions risk exclusion if they overlook informational and institutional barriers; and tailoring programmes to the realities of informal sector households, through flexible finance, community-based awareness, and trust building, offers a more equitable route to scaling CRE. While situated in Northern Nigeria, the approach yields transferable insights for context sensitive energy transition policy in low resource settings across SSA. Findings reflect Nigeria's institutional and socio-economic context; any relevance to Sub-Saharan Africa is hypothesis-generating and should be established through local data and replication. We contribute a context sensitive socio structural framework and an MNL design that uses relative income bands and awareness interactions, yielding actionable, equity-oriented policy insights for Sub-Saharan Africa (SSA).

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KEYWORDS

Community renewable energy, net-zero, bottom-up transition policies, sub-Saharan Africa, sustainable energy transitions, socio-structural determinants, decentralized energy systems.

HIGHLIGHTS

- Community renewable energy adoption in Northern Nigeria is shaped by income, education, and awareness in combination, not isolation.
- Awareness stands out as a cost-effective policy lever, with effects that multiply when targeted to lower-income or moderately educated households.
- Informal-sector workers face lower adoption likelihoods, suggesting the need for micro-finance and flexible payment models alongside awareness strategies.
- Relative income bands, rather than exact earnings, provide a culturally sensitive basis for subsidy targeting and can be replicated in other low-income contexts.
- Findings inform broader SSA policy debates by showing how layered socio-economic vulnerabilities can be addressed through integrated, trust-based interventions

3.1 Introduction

The global climate agenda increasingly prioritizes energy justice, emphasizing the need to transition energy systems towards sustainable, low-carbon models while ensuring fairness and equity [1,2]. This shift is particularly significant in Sub-Saharan Africa (SSA), where energy access challenges persist, underscoring the urgency of decentralized renewable energy (RE) solutions [3,4]. Notably, the commitment to energy justice was reaffirmed at COP28 in Dubai, emphasizing the importance of inclusive approaches to ensure no one is left behind in the global transition to clean energy [5]. Consequently, there has been a global push to transition from centrally operated fossil-fuel-based energy systems to decentralized, low-carbon models [6–10]. Findings reflect Nigeria's institutional and socio-economic context; any relevance to Sub-Saharan Africa is hypothesis-generating and should be established through local data and replication.

In the global south, centralized grids frequently fail to stimulate the anticipated economic activities that underpin sustainable development [11]. This challenge is particularly acute in SSA, where limited institutional capacity and energy access gaps necessitate bottom-up approaches such as Community Renewable Energy (CRE) initiatives [12,13]. Such initiatives empower citizens to actively participate in their energy systems, marking a fundamental shift in the role of end-users from passive consumers to active "prosumers" [14,15].

Despite the region's considerable solar photovoltaic (PV) potential, enabled by high solar irradiation levels, renewable energy utilization in SSA remains low [16–18]. SSA accounts for 17% of the global population but contributes only 4% to global power supply investment and holds less than 1% of the world's installed solar PV capacity [19]. Over 55% of the region's population lacks access to electricity, highlighting the prevalence of energy poverty [20–22]. By embracing RE solutions such as CRE, nations in SSA could address energy poverty, stimulate economic growth, create jobs, and reduce greenhouse gas emissions, thereby contributing to both national and regional climate mitigation efforts [23–26]. The International Energy Agency [19] posits that reliable energy supply in SSA requires nearly quadrupling current investment to around \$120 billion annually by 2040. Given the significant financial burden on state

budgets in low-income regions [27,28], there is a growing consensus on the need to empower citizens to actively shape local energy initiatives through CRE.

CRE encompasses diverse models, including grassroots efforts led by local communities [29,30], government-steered projects [31,32], and private-sector-supported initiatives [33,34]. These models are tailored to socio-economic, political, and institutional contexts to achieve localized energy transitions. Grassroots CRE initiatives, in particular, have proven instrumental in fostering sustainable energy practices through local engagement and empowerment [35,36]. While early studies laid the groundwork for understanding CRE's potential [15], recent research highlights the evolution of CRE models and their implementation, particularly in the global north [37,38].

Building on this, recent analyses, such as those by Zebra (et al., 2021, 2023), emphasize the critical role of hybrid renewable energy systems (HRES) in improving energy access in remote SSA communities. Such studies address techno-economic and sustainability challenges while fostering community engagement for long-term viability. However, despite the progress in HRES research, specific focus on CRE initiatives remains underexplored, particularly in regions like Northern Nigeria. In response, this analysis examines how awareness and key socio-structural factors influence CRE adoption, offering an Afrocentric perspective to complement and advance existing discussions.

Although some quantitative studies have analyzed factors influencing citizen participation and attitudes towards CRE, gaps persist in understanding the unique socio-economic and cultural dynamics of SSA. Despite robust research efforts [25,41–44], the application of advanced quantitative tools, such as Multinomial Logit (MNL) regression models, to analyze determinants of community participation remains limited. This analysis addresses that gap by providing novel empirical evidence of CRE acceptance in Northern Nigeria, a context often underrepresented in the literature.

Existing literature on CRE in SSA highlights diverse applications, including solar microgrid designs, rural water supply, and healthcare electrification [45,46]. However, barriers such as governance challenges, financial constraints, and socio-cultural opposition necessitate tailored interventions [47,48]. To address these barriers, recent

research underscores the importance of governance frameworks, stakeholder collaboration, and technological innovations in advancing CRE initiatives [42,49].

In response to these challenges, the analysis investigates the determinants of citizen adoption of CRE initiatives in SSA, focusing on Northern Nigeria. Using an integrative review approach, it synthesizes theoretical and empirical works to provide actionable insights. Recent studies (post-2020) were prioritized, complemented by seminal works to ensure a robust contextual foundation. The review process identified critical themes, including determinants of CRE participation, policy frameworks, and socio-economic dynamics in SSA. The findings aim to bridge knowledge gaps, inform policy development, and support the broader adoption of CRE to address energy poverty and achieve sustainability goals.

The remainder of the paper is structured as follows: Section 3.2 provides a foundational review of CRE, its definitions, and its relevance to SSA, emphasizing key challenges and determinants. Section 3.3 outlines the methodology, followed by results and discussion in Section 3.4. Finally, Section 5.5 concludes with policy implications and recommendations for facilitating CRE adoption in Nigeria.

3.2 CRE foundational review

The discourse surrounding CRE has gained traction globally in recent years, reflecting a growing emphasis on community-driven efforts towards RE adoption and energy justice [50]. This surge in interest is underpinned by the belief that decentralized RE projects such as CRE hold the potential to catalyze systemic change and facilitate a comprehensive transformation of energy systems [38,51]. The significance of understanding citizens' motivations to participate in CRE is pivotal for accelerating this transition [52,53]. Thus, the successful management of energy transitions at decentralized levels hinges upon the acceptance and active participation of citizens [52]. This resonates with the broader call for inclusive approaches to sustainability transitions [50].

Recent studies underscore the importance of contextually relevant strategies for inclusive energy transitions. For example, Sciullo et al., [38] and van der Waal et al., [51] highlight how localized socio-economic and cultural contexts shape the success

of energy transitions, particularly in underserved regions like SSA. Broadening the conversation beyond Eurocentric contexts is crucial to achieving true global inclusivity and energy justice, in line with the principle of 'leaving no one behind. In this context, understanding the factors influencing citizens' willingness to engage in CRE becomes essential. This highlights the need for more tailored, inclusive strategies to ensure effective energy transitions in underserved regions.

3.2.1 Concepts of CRE

There is no singular, universal definition of CRE. Variations in terminology often hinge on contextual factors or geographic distinctions. Variations in terminology and structure may depend on geographic and socio-economic contexts, making the concept inherently flexible [54]. For the purpose of this study, CRE refers to decentralized renewable energy initiatives that are locally managed, collectively financed, and designed to serve a specific group or locality through participatory governance mechanisms. In this framing, CRE goes beyond technology to encompass embedded social processes, community ownership, and shared benefits. Nevertheless, CRE share certain foundational characteristics: they are decentralized [55–58], locally embedded and empowering women [35,52,55,59,60], voluntary and driven by citizen engagement [15,52,59,61]. Even though scholars like Seyfang et al., [62] and Strachan et al.,[63], argue that CRE might be challenging to analyze due to the variety of interpretations, foundational studies [15,64] noted that, despite variations of interpretation in the CRE notion, it retains a core identity; decentralized, citizen-driven, and bottom-up participation aimed at supporting sustainable energy practices.

Building on these foundations, recent research also affirms these CRE characteristics by broadening CRE's definition to include that they prioritize local engagement, foster social cohesion, and generate economic and environmental benefits [35,52]. Other recent research highlights the evolution of CRE models, including government-steered and private-sector-driven projects [32,33]. These models blend local engagement with institutional frameworks to achieve sustainability goals [38]. The flexibility of CRE allows it to adapt to diverse socio-political contexts, making it an effective tool for addressing energy poverty and promoting sustainability [37]. However, some scholars argue that the term "community energy," when used imprecisely, can potentially impede the creation of successful policies [65,66]. In practice, the adoption of CRE is often conditioned by socio-structural and perceptual variables such as income,

education, occupation, and awareness that mediate how communities engage with these models.

Extending the CRE discussion, academics, such as Conradie et al., [53] favor the conceptual framework and terminology found in the Renewable Energy Directive (EU) 2018/2001 within the European Union, commonly referred to as RED II. Within RED II, CREs are defined as legal entities engaged in energy production and consumption, comprising individuals, local authorities, and small and medium-sized enterprises (SMEs) who participate voluntarily. Their overarching aim is to deliver economic, social, and community-oriented benefits, rather than pursuing pure financial gains.

More recently, scholars such as Busch et al.,[52], conceptualize CRE as energy (sub) systems that are controlled and managed by the local population, where the local population benefits economically, socially and environmentally [35,58,59,61,64,67]. One defining feature is emphasis on citizen-led efforts rather than governments or business influence [55,64,66,68]. The argument for non-government interference serves as strategic niche innovation that drives societal and technological shifts toward sustainable energy transitions [38]. This perspective is embedded in community values that promotes solidarity, self-sufficiency and empowerment through local engagement [69].

However, scholars like Bauwens [68], Herbes et al., [70] and Kalkbrenner & Roosen, (2016), contend that understanding the factors that drive citizens' involvement in CRE is crucial to accelerating the transition to sustainable energy systems. Building on this, Steg and colleagues [72–76] emphasize the significant role of personal values such as biospheric and altruistic motivations, as well as identity factors, in influencing participation in community energy initiatives. This body of work highlights how intrinsic motivations often outweigh external incentives in encouraging sustainable energy behaviors. Her work highlights how intrinsic motivations often outweigh external incentives in encouraging sustainable energy behaviors. Additionally, contextual factors such as access to information, social norms, and perceived community support can either facilitate or hinder participation. Incorporating these perspectives provides a nuanced understanding of the interplay between individual motivations and structural enablers in adopting CRE.

Despite the recognized significance of understanding citizens' intentions to participate in CRE, a notable knowledge gap persists especially in regions such as SSA where political, economic, and social dynamics diverge markedly from Eurocentric contexts. While existing studies largely focus on Europe, where high education levels and institutional trust often underpin CRE participation [53], these determinants may not hold true for SSA. Here, factors such as renewable energy awareness assume greater significance, particularly in Nigeria where large sections of the population face lower levels of formal education. Addressing this gap requires centering SSA's unique socio-economic and cultural landscape, thereby uncovering the nuanced drivers and barriers that influence local engagement. Such an Afrocentric lens moves beyond broad generalizations, enabling more precise, context-sensitive policy interventions that directly respond to SSA's distinct challenges and opportunities ultimately paving the way for more effective and inclusive energy transitions.

3.2.2 Challenges and opportunities of CRE in Sub-Saharan Africa

Sub-Saharan Africa (SSA) faces unique challenges in energy access, with over 600 million people lacking reliable electricity [19]. Despite the region's abundant solar resources, installed solar PV capacity remains below 5 GW, highlighting a significant gap in renewable energy adoption. CRE offers a promising solution, leveraging local engagement and decentralized approaches to address energy poverty [20,25]. In practice, the adoption of CRE is often conditioned by socio-structural and perceptual variables, such as income, education, occupation, and awareness that mediate how communities engage with these models.

Key studies emphasize the importance of governance structures, stakeholder collaboration, and technological innovations in fostering CRE adoption [47,48]. For example, Zebra et al., [39] provide critical insights into hybrid renewable energy systems (HRES), identifying cost barriers and governance limitations that parallel challenges in CRE. Their findings on the levelized cost of energy (LCOE) demonstrate how hybrid mini-grids outperform centralized grids in cost-effectiveness and reliability, making them suitable for rural SSA communities [39]. In addition, Koirala et al., [12] underscore the role of socio-technical configurations in enabling decentralized energy systems. Their actor-network approach highlights the importance of community participation in creating sustainable energy solutions, aligning with CRE's emphasis on grassroots involvement. Similarly, van der Waal et al., [77] advocate for regulatory

sandboxes, allowing participatory experimentation to optimize CRE models for specific contexts. These frameworks are particularly relevant for SSA, where policy innovation is crucial for overcoming institutional inertia and resource constraints.

Kyere et al., [42] identify barriers such as financial constraints and socio-cultural opposition, while emphasizing the need for localized governance frameworks. Some researchers highlight practical applications of CRE, including solar microgrid designs and rural healthcare electrification, which demonstrate the potential of decentralized systems to provide cost-effective solutions [45,46]. Recent studies also underscore the critical role of international aid, digitalization, and regulatory environments in shaping the RE landscape [44,49]. However, tailored interventions are necessary to address SSA's unique socio-economic and political dynamics, which diverge significantly from Eurocentric contexts [38]. Broadening the focus beyond technical and economic factors, CRE initiatives must also prioritize community engagement and cultural alignment to achieve long-term viability.

3.2.3 Nigeria's Energy Landscape: A Case for CRE

As the most populous nation in SSA, Nigeria exemplifies the challenges and opportunities associated with the adoption of CRE. Despite the country's vast renewable energy potential, approximately 70% of Nigerians lack reliable electricity [78], with many relying on polluting and costly hydrocarbon generators [79–83]. CRE offers a sustainable alternative, providing cleaner, community-driven energy solutions [43].

The persistent energy deficit in Nigeria underscores the need for decentralized approaches. However, CRE remains a nascent concept in the country, hindered by weak institutional support and low public awareness. Recent efforts emphasize the importance of localized governance, financial incentives, and stakeholder collaboration to overcome these barriers [84,85]. Studies highlight that tailored policy interventions can enhance CRE adoption, particularly in underserved regions like Northern Nigeria, where socio-economic disparities are pronounced [86]. These disparities reflect broader socio-structural variables, including income, education, occupation, household size, and gender that consistently shape energy adoption outcomes across Sub-Saharan Africa [87–89].

Nigeria's economic disparity between the prosperous southern region and the disadvantaged rural north further complicates energy access. Northern Nigeria's low disposable income and energy deficiencies present unique challenges for CRE implementation [90]. However, these challenges also provide an opportunity to explore innovative solutions tailored to the region's needs. For instance, solar PV systems hold the potential to improve energy access while supporting local economic growth [45].

3.2.4 Addressing Research Gaps and Advancing CRE in SSA

While prior studies have identified critical socio-economic and cultural factors influencing CRE participation globally, significant gaps remain in applying advanced quantitative methods to SSA contexts [25,41,42]. Addressing this gap, this study employs MNL model to investigate determinants of CRE adoption in Northern Nigeria. Recent literature also highlights the importance of integrating community engagement, policy frameworks, and technological innovation, alongside personal values and social norms, to enhance CRE adoption and sustainability outcomes [12,39,73]. Building on these insights, the study synthesizes theoretical and empirical works to provide actionable recommendations for policymakers and stakeholders aiming to promote equitable CRE uptake in SSA. Based on these identified gaps, it addresses the following research question: Does awareness of sustainable energy and key socio-structural factors influence the adoption of CRE initiatives in Northern Nigeria? This study responds to these gaps by explicitly modelling socio-structural, socio-cultural, perceptual, and technological variables, thereby linking household-level dynamics to broader policy debates on CRE adoption in Northern Nigeria.

3.3 Methodology

3.3.1 Survey Design

Design, collection and analysis of data was administered in three phases (Figure 3-1). Phase one (pre-field work) covered all desk research, literature review and paperwork. Phase two, was data collection and conducted in accordance with ethical standards and protocol. Participants were assured of anonymity, confidentiality and freewill to withdraw from the study at any time. No personal details were collected. Samples were restricted to majors (i.e. age 18 and older). The use of mobile technology for data collection ensured efficiency and timely completion of the survey. The KoboToolbox application [91] was employed to host the survey questionnaires on the mobile phones of volunteer evaluators and administered to respondents. Phase three (post-field

phase) was data cleaning on spreadsheet and using STATA Version 17.0 software for the MNL model.

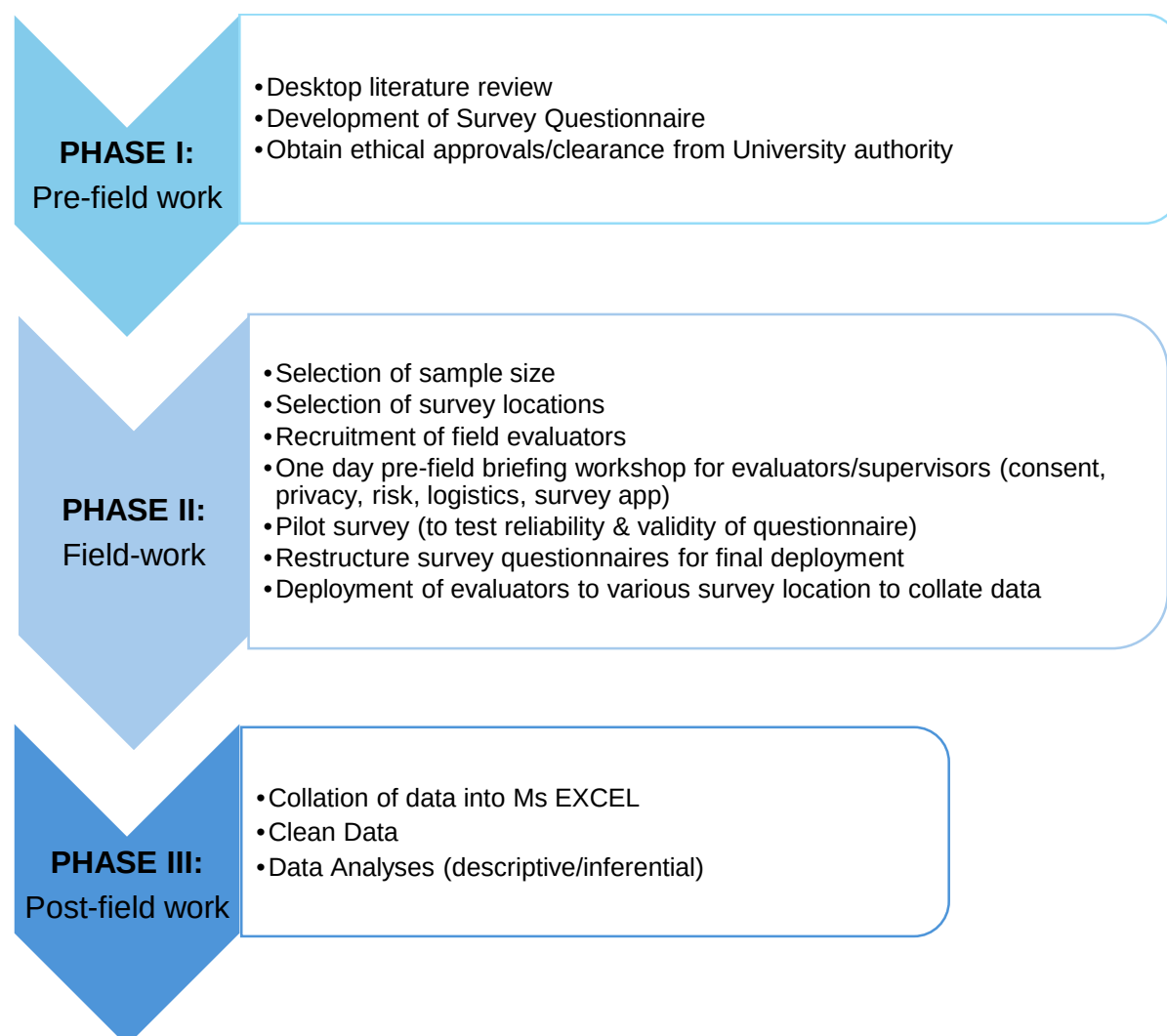


Figure 3-1. Preliminary Phases of the Research Process.

Figure 3-1 outlines the staged research design for this study, beginning with literature review and instrument development, and extending through fieldwork and data analysis. It should be noted that while the study was informed by a wide-ranging literature base, it did not adopt a formal systematic review methodology (such as PRISMA).

3.3.2 Study Area

Due to resource constraints and security concerns, the study area was limited to two states from each region of northern Nigeria. The states were selected to reflect the demographic diversity of Northern Nigeria, divided into three main geo-political zones, namely, north-central, north-west and north-east (see Figure 3-2). This represented a

sample of Northern Nigeria with a population of 122,305,437, constituting 56.4% of the total population of Nigeria [92]. Northern Nigeria spans 660,000 square kilometers, covering about 79.4% of Nigeria's total landmass [93]. The states included in the study are *Plateau* and *Nassarawa* from the North-Central region, *Bauchi* and *Gombe* from the North-East region, and *Jigawa* and *Kano* from the North-West region (Figure 3-2). The survey map in Figure 3-2 illustrates (A) Nigeria, highlighting the survey areas covering each geopolitical zone, including the states and communities in Northern Nigeria that were visited, and (B) an inset map of Africa showing Nigeria shaded in grey.

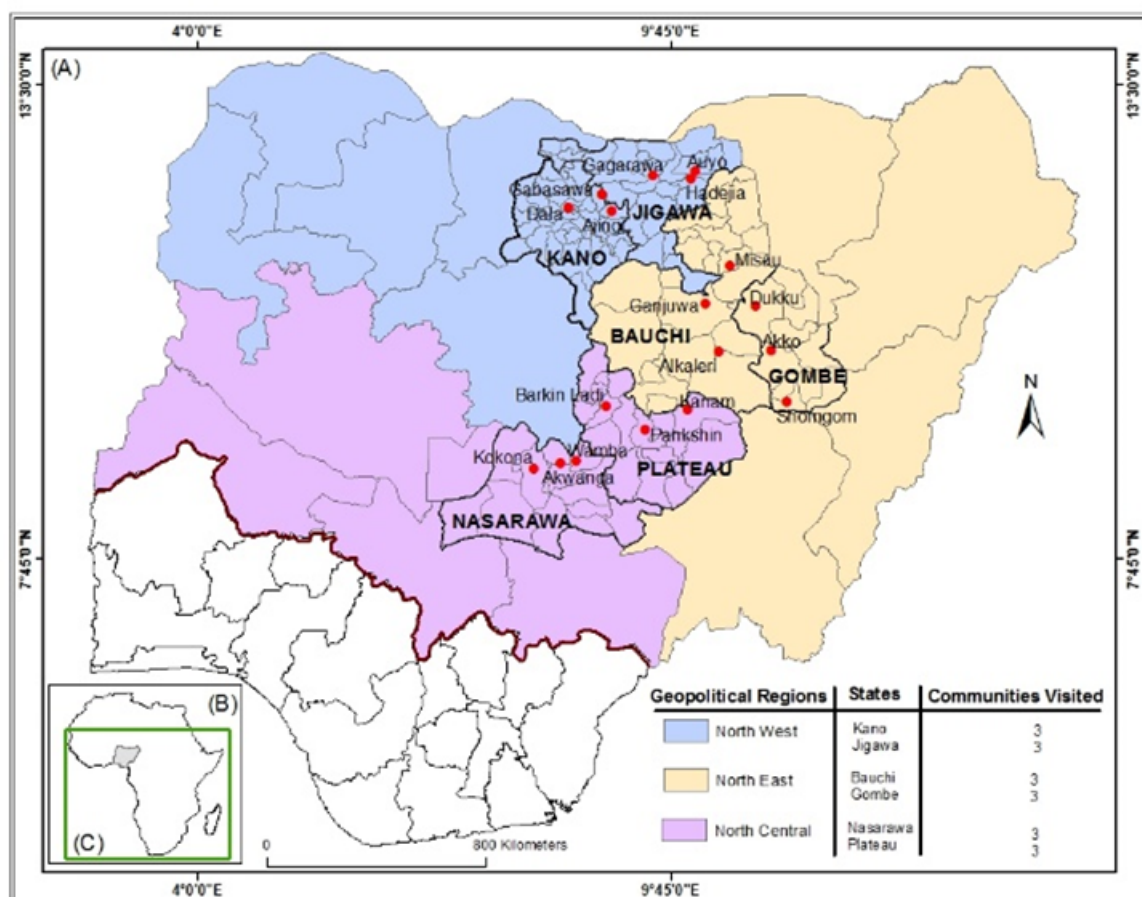


Figure 3-2. Study Area in Nigeria.

Given the extensive land area of Northern Nigeria, reaching the entire population for data collection was impractical. To address this limitation, the study utilized the concept of sampling, which posits that a well-chosen sample can effectively represent the larger population [94]. Consequently, a mixed-method approach was employed to obtain a representative sample. The non-probabilistic cluster sampling technique leveraged the existing division of Northern Nigeria into three geopolitical zones, North-

East, North-Central, and North-West, each treated as a distinct cluster. To ensure comprehensive coverage within each zone, the states within each zone were further considered as clusters. Using the non-probabilistic convenience sampling method [95], two states were selected from each zone. This approach was adopted due to prevailing insecurity in Northern Nigeria during the data collection period, prioritizing the safety of the research team.

Subsequently, a probabilistic sampling strategy was employed to further refine the sample. The Local Government Areas (LGAs) within each selected state served as strata. Simple random sampling was used to select three LGAs from each state. The population size of households within the selected LGAs was then determined. Given the total sample size across the 18 LGAs was too large to feasibly cover, the Slovin formula was applied to calculate the number of households to sample from each LGA (Table 3-1). A detailed version of Table 3-1 can be found in Appendix A. The sampling design therefore combined purposive selection of states with stratified random sampling of LGAs within each state, making the sample partly non-probability at the state-selection stage and probability-based within states; this limits the external validity of estimates beyond the surveyed locations.

3.3.3 Sample Size

To determine the selection criteria in Phase 2 of our methodology (Figure 3-1), the sampling interval is N/n ($19/3 = 6\text{th}$); we selected every sixth local government under each state for a 95% confidence level and 5% margin of error. For multi-level sampling with no prior knowledge of the population's behavior, Slovin's formula [96] was employed to calculate the sample size as follows, where n is the sample size, N is the population size, and e is the margin of error:

$$n = \frac{N}{(1 + Ne^2)} \quad (3-1)$$

We aimed for higher accuracy by setting the confidence level at 95% and margin of error at 5%. The number of responses collected was 583, but after data cleaning, the final sample size was 559. These samples were statistically selected across the six states representing the three geo-political zones in the country (Table 3-1, Appendix A), ensuring every individual within the household population size [97] had an equal chance of selection.

A stratified random sampling technique was applied, whereby the proportion of each **stratum** (state) within the population was calculated, and samples were randomly selected in the same proportion from each stratum. The stratified sample size formula is given as:

$$N_h = \left(\frac{n}{N}\right) \times n_h \quad (3-2)$$

where n is the sample size, N is the population size, n_h is the stratum size. Using the above formula, we generated the sample distribution in Table 3-1.

Table 3-1. Survey Sample Distribution.

Geopolitical zone	States	Population size (Household)	Proportion (%) of Population	Stratified sample Size
North-East	Bauchi	853	14%	82
	Gombe	906	16%	87
North-Central	Plateau	1,004	18%	95
	Nasarawa	999	16%	95
North-West	Jigawa	981	17%	93
	Kano	1,107	19%	107

3.3.4 Data Acquisition

Prior to full-scale deployment of the survey instrument, a pilot study was conducted to assess both reliability and validity. A total of 35 questionnaires—approximately 6.25% of the intended sample—were administered in a suburban community in Jos, Plateau State (see Figure 3-2). Reliability, assessed using Cronbach’s alpha, yielded $\alpha = 0.703$, exceeding the commonly used 0.70 threshold. For validity, convergent validity was examined across four logically related survey questions, resulting in a coefficient of 0.624, indicating acceptable coherence [98,99]. We used five-point Likert-type items for closed-ended constructs to standardize administration across multiple LGAs and languages, reduce interviewer discretion and interview time, and ensure comparability for the multinomial logit analysis (AMEs and predictive margins); deeper, open-ended probing was reserved for the qualitative interviews reported in Chapter 4. This division of labor between a standardized, closed-ended survey and open, semi-structured interviews follows the mixed-methods design set out in Chapter 1 (Section 1.5.4).

The final survey instrument consisted of three sections: (1) socio-demographic characteristics, (2) renewable-energy awareness, and (3) willingness to adopt CRE. The survey was administered between 25 August and 2 November 2022, in collaboration with two academic staff and 18 final-year undergraduate students from the University of Jos, Nigeria. A preparatory workshop trained all enumerators on survey objectives, ethical considerations, privacy protocols, and procedures for community engagement. Enumerators were equipped with mobile devices running KoboToolbox, a widely used open-source digital data-collection platform. The platform facilitated real-time capture and upload of responses using the structured five-point Likert-type scale for closed-ended items. Median survey completion time was 35 minutes, with most respondents completing all sections. Enumerators were trained in culturally sensitive practice, particularly for initial contact with traditional authorities and community leaders; this was essential for securing access and obtaining local interpreters where needed, especially in areas with strong oral traditions or linguistic diversity. These preparatory steps enhanced response accuracy, improved participant engagement, and minimized ethical or procedural risks in rural and peri-urban Northern Nigeria. To guide interpretation, the “Model Variables and Coding Approach” and “Statistical Model Specification” sections present the context-sensitive variable coding and model set-up; the regional context is not modelled as a standalone covariate but is reflected in the operationalization of income, awareness, and occupation variables.

3.3.5 Model Variables and Coding Approach

The empirical specification draws on variables identified in both theory and prior empirical work on renewable-energy adoption in Sub-Saharan Africa. These variables were coded to reflect the socio-structural dimensions that shape household energy decisions and to enhance comparability across households. Consistent with the SSA setting, several variables were structurally adapted: household income is specified in relative percentage bands of a regional income benchmark; awareness is coded as a binary indicator and interacted with income and education to reflect trust-mediated information flows; and occupation categories are collapsed to distinguish informal from formal labor contexts (Appendix A, Variable Coding and Crosswalk).

In this study, sociocultural conditions are operationalized via observed proxies within the covariates: education (including non-formal/religious/adult literacy), household

size and marital status (family structure), occupation class, and an awareness indicator analyzed—also via interactions—as trust-filtered information rather than mere exposure.

For analytical clarity, explanatory variables were organized into four conceptual groupings. Socio-structural factors include age, gender, marital status, household size, education, and occupation. These durable characteristics shape socio-economic positioning and influence access to, and participation in, energy decision-making. Socio-cultural factors capture shared norms, values, and community practices (e.g., trust in institutions, participation patterns), while perceptual factors represent individual attitudes and awareness of CRE. Finally, technological factors describe infrastructural enablers and constraints such as grid connectivity or the availability of technical skills. In this dataset, socio-structural and perceptual variables were directly operationalized; socio-cultural and technological dimensions informed the analytical framing and policy discussion but were not separately modelled due to data limitations.

The dependent variable measures respondents' commitment to CRE adoption using a five-point Likert-type scale (1 = Not Committed; 5 = Highly Committed) and is treated as nominal in the multinomial logit model to avoid assuming equidistance between categories [100,101].

Household income was coded as percentage bands of a regional benchmark, since disclosing exact earnings is culturally sensitive in rural and peri-urban northern Nigeria. This approach respected prevailing norms around financial privacy, improved response reliability, and ensured comparability across households. Five bands were defined, consistent with the descriptive statistics: < 5% (reference), 5–9%, 10–14%, 15–20%, and > 20%. Using bands provides a credible proxy for affordability without requiring precise income figures and has precedent in the survey methods literature [102].

Awareness of CRE was measured as a binary indicator, coded 1 if the respondent had heard of or encountered CRE technologies or projects, and 0 otherwise. To capture conditional effects, awareness was interacted with education and income in extended specifications, allowing the analysis to test whether information uptake varies by structural position [103–108].

Occupation, a marker of economic engagement and social status, was included to distinguish between formal and informal labor contexts. For modelling purposes, categories were collapsed into six groups: Unemployed (reference), Farming, Trading, Civil service, Private sector, and Other. The more detailed occupational labels presented in the descriptives (Table 3-2) are cross-walked to these six modelling categories in Appendix A (Variable Coding and Crosswalk). Although occupation was not among the strongest predictors, retaining it improved model realism by capturing differences in income stability and institutional exposure.

Education was classified to align with Table 3-2 and the regression coding scheme: No formal education (reference), Primary, Secondary, Diploma/Certificate, Degree, and Masters. In this specification, “tertiary” education is disaggregated into Diploma/Certificate, Degree, and Masters to reflect the sample distribution and to enhance interpretability; the reference category remains No formal education. This categorization captures both cognitive access to information and exposure to institutional environments, each of which influences perceptions of cost, reliability, and risk.

Demographic controls were specified as follows: Gender was coded 1 = male and 0 = female (reference). Marital status was grouped into Single (reference), Married, Widowed, and Divorced. Age was stratified into 18–25 (reference), 26–35, 36–45, 46–60, and 61+. Household size was categorized as 1–4 (reference), 5–8, and ≥ 9 . All categorical variables were dummy-coded, with reference groups chosen to reflect the lowest exposure or socio-economic tier, in line with standard practice in policy-oriented MNL modelling [109]. For ease of cross-referencing with the estimation tables, the reference categories are: Education = No formal education; Occupation = Unemployed; Income = $<5\%$; Age = 18–25; Marital status = Single; Gender = Female; Household size = 1–4; and Awareness = Not aware (0).

While no variable was explicitly labelled as “financial constraint,” household income bands served as a proxy for affordability, and the awareness indicator captured information access. Both dimensions are shaped by wider economic and infrastructural disparities in SSA [110–112]. For some variables, the number of valid responses was slightly lower than the full sample of 559 due to item non-response;

these cases were addressed through listwise deletion, a standard approach in survey-based adoption studies.

3.3.6 Theoretical and Analytical Framework

The analytical framework underpinning this study draws upon and adapts established theories of technology adoption while integrating contextual realities specific to SSA. In conventional Euro-American literature, energy adoption behaviors are commonly explained using paradigms such as Rogers' Diffusion of Innovation Theory, the Technology Acceptance Model (TAM), and the Unified Theory of Acceptance and Use of Technology (UTAUT) [113–117]. These models foreground individual decision-making based on perceived usefulness, access, and innovation diffusion dynamics typically within relatively stable institutional, infrastructural, and informational ecosystems.

However, these assumptions often diverge sharply from energy realities in regions like Northern Nigeria, where access decisions are shaped by deep-seated cultural beliefs, informal economic structures, distrust in government institutions, and the legacies of failed or fraudulent energy interventions [118–122]. In these contexts, individual behavior cannot be meaningfully understood without considering the wider social and structural constraints within which it is embedded.

To address this, the present study employs a socio-structural analytical framework that integrates individual-level attributes such as education, gender, and awareness with broader structural dimensions, including occupational type, income category, and household size. These dimensions are not treated as passive descriptors but as active mediators of agency and capacity in energy decision-making processes. For instance, income in this setting is not merely a proxy for affordability; it is deeply embedded within informal labor dynamics and communal household obligations, both of which influence perceived priorities and risk assessments around energy investments. Similarly, awareness is not simply a function of exposure to information; it is filtered through the perceived credibility of information sources whether governmental, community-based, or private and is therefore highly contingent on social trust [123,124]. Accordingly, the model embeds these sociocultural dynamics through empirical proxies: relative income bands, trust-filtered awareness, education type/level, household structure, and occupation class, thereby operationalizing our

SSA-specific framework within the MNL specification. Classical adoption models (Diffusion of Innovations, TAM, TPB) inform the literature; however, given SSA's institutional and trust constraints, we adopt a context-sensitive socio-structural framework and implement it via awareness $\times$ income and awareness $\times$ education interactions in the MNL (see Section 3.4.1.4).

This analytical perspective also brings governance to the forefront, acknowledging that local institutional credibility and previous experiences with energy programs critically influence adoption behavior. Even where technical merit exists, communities may resist participation if past interventions have eroded trust [71,125–128]. In such cases, governance failures function not as peripheral obstacles but as central variables in enabling energy adoption and transitions.

The framework employed in this study rests on three central assumptions. First, socioeconomic capacity, proxied by variables such as income, occupation, and education, which together directly shape willingness to adopt CRE, not only through financial affordability but via structural opportunity and constraint. Second, contextual awareness, measured through exposure to sustainable energy information and initiatives, moderates this relationship by either amplifying or dampening the influence of these structural factors, depending on the perceived legitimacy and accessibility of the information. Third, the interaction between awareness and these structural conditions is non-linear; that is, the impact of awareness on adoption is conditional on one's socioeconomic position, particularly in low-resource contexts.

By operationalizing this framework through a MNL Model and including interaction effects across awareness, income, and education, this study diverges from traditional linear models of adoption. It instead captures the layered and context-specific realities that define renewable energy transitions in marginalized communities. The resulting insights are not only grounded in local lived experiences but also carry broader implications for understanding energy behavior in other underserved regions of the Global South [129–133].

This context-specific framework not only clarifies the analytical departure from Euro-American approaches but also contributes to decolonizing energy scholarship by centering structural inequality, governance failure, and cultural nuances in the study of renewable energy transitions. Ultimately, this theoretical orientation provides

conceptual clarity on the departure from Euro-American models and contributes to the decolonization of energy scholarship. By centering structural inequality, governance experience, and cultural nuance, it offers a more holistic and policy-relevant understanding of CRE adoption in SSA.

3.3.7 Descriptive Overview

Laying the empirical groundwork for the inferential models presented in Section 4, this section presents a descriptive overview of the survey data, offering insights into the demographic, socioeconomic, and awareness-related characteristics of the respondents. The descriptive statistics summarized in Table 3-2 provide a foundational understanding of the sample's structure and inform the interpretation of inferential results that follow.

The survey recorded 73.5% male and 26.5% female respondents, as detailed in Table 3-2. Males were slightly older on average (mean = 39.5 years) than females (mean = 34.7 years), with a broader age range (18–77 vs. 18–62). This gender distribution reflects socio-cultural norms in Northern Nigeria, where religious and traditional values often confine women to domestic roles, limit their public engagement, including participation in research. While energy needs are generally universal, usage patterns and intensity often vary by gender due to gender-specific roles within households. These disparate patterns underscore the need to address gender gaps in research participation and design culturally sensitive frameworks for CRE access and engagement.

Table 3-2. Descriptive Statistics of the variables.

Variable	N	%	Mean	StdE	Min	Max
Dependent Variable			3.95	0.033	1	5
Not committed (1)	4	0.7				
Slightly committed (2)	12	2.1				
Moderately committed (3)	117	20.9				
Committed (4)	291	52.6				
Highly committed (5)	127	23.7				
Age (Years)			38.195	11.704	18	77
16 - 25	81	14.5	22.691	2.256	18	25
26 - 35	179	32.0	30.715	2.974	26	35
36 - 45	161	28.8	40.298	3.032	36	45
46 - 55	87	15.6	50.460	2.852	46	55
56 - 65	41	7.3	59.537	3.083	56	65
66 - 75	9	1.4	68.778	1.716	66	70
Above 75	1	0.4	77	-	77	77

TOTAL	559	100.0				
Gender					0	1
Male	411	73.5	39.467	11.872	18	77
Female (Ref)	148	26.5	34.662	10.479	18	62
TOTAL	559	100.0				
Marital Status					1	3
Married	391	70.0	3.953	0.795		
Single	137	24.5	3.925	0.722		
Widow/Widower	31	5.5	4.065	0.680		
TOTAL	559	100.0				
Occupation					1	12
Charity	8	1.4	4.375	0.518		
Housing	24	4.3	3.167	0.482		
Community	16	2.9	3.938	0.680		
Local Government	95	17.0	4.000	0.758		
University	23	4.1	4.136	0.710		
NGO	20	3.6	3.947	0.524		
Health	18	3.2	3.611	0.778		
Local Government	62	11.1	4.183	0.892		
Small-Scale business	109	19.5	3.916	0.779		
Artisan	75	13.4	3.919	0.754		
Farmers	77	13.8	4.026	0.725		
Others	32	5.7	3.968	0.752		
TOTAL	559	100.0				
Educational Qualification					1	6
None	36	6.4	3.829	0.822		
Primary	60	10.7	3.797	0.867		
Secondary	204	36.5	3.926	0.738		
Diploma Certificate	180	32.2	3.994	0.794		
Degree	68	12.2	4.090	0.690		
Masters	11	2.0	4.200	0.632		
TOTAL	559	100.0				
Household Size					1	4
2 People	81	14.5	3.913	0.697		
3 People	100	17.9	3.818	0.787		
4 People	152	27.2	3.886	0.722		
At least 5 People	223	39.9	4.077	0.808		
TOTAL	556	99.5				
Income					1	5
<5%	180	32.2	3.680	0.838		
5-9%	222	39.7	4.005	0.657		
10-14%	105	18.8	4.097	0.693		
15-20%	29	5.2	4.379	0.942		
>20%	14	2.5	4.786	0.426		
TOTAL	550	98.4				
Awareness					0	1
Yes	299	53.5	4.142	0.655		
No	255	45.6	3.730	0.837		
TOTAL	554	99.1				

Note: N varies across variables due to item non-response. Standard errors are reported for continuous variables; percentages are based on valid responses.

Table 3-2 also reports the distribution of the dependent variable. Of the 559 respondents, 74.8% were either “Committed” (52.6%) or “Highly Committed” (23.7%), while very few fell into categories 2 (“Slightly Committed,” 2.1%) or 3 (“Moderately Committed,” 20.9%). Due to the sparsity of categories 2 and 3, these were merged

during sensitivity checks to enhance statistical stability. The results, however, were substantively unchanged, underscoring the robustness of the specification.

Age distribution was another critical variable examined, and it showed a youthful population, with 60.8% of respondents aged between 26 and 45 years. The average respondent age was 38.2 years (SD = 11.7), indicating moderate variation. In this region, early marriage and youth-led households are common, highlighting the importance of targeting CRE education and financing to younger heads of households who are active decision-makers. The lowest representation (1.8%) came from respondents aged 66 years and above.

Regarding marital status, the sample included 70% married, 24.5% single, and 5.5% widowed respondents. Widowed individuals reported the highest adoption scores (mean = 4.06), possibly reflecting energy-related needs in single-adult households. Married respondents followed closely (mean = 3.95), while single individuals had a slightly lower average (mean = 3.93). These differences suggest that family structure may influence willingness to adopt CRE.

Educational attainment was varied: 53.6% had secondary education or less, 32.2% held diploma certificates, and only 14.2% held university degrees or postgraduate qualifications. Higher education was positively associated with CRE adoption scores, with master's degree holders averaging 4.20. The correlation between education and adoption underscores the role of knowledge and literacy in shaping sustainable energy transitions.

Occupational categories reflected the predominantly rural and peri-urban context of the study. Small-scale business owners (19.5%), local government employees (17.0%), farmers (13.8%), and artisans (13.4%) were the most represented groups. Charity workers (1.4%) exhibited the highest mean adoption score (4.38), while housing-related occupations recorded the lowest (3.17). These findings suggest that employment type may influence both awareness and perceived benefits of CRE.

Household size was also examined, with the largest group (39.9%) comprising households with at least five members. Households with fewer members were progressively less common. Larger households generally reported higher adoption scores, consistent with increased energy needs and economic pressure to find reliable energy solutions.

In terms of income, most respondents (71.9%) reported household earnings below 10% of a regional reference band. Only 7.7% reported earnings above 15%. Income was positively correlated with adoption scores; those in the highest bracket (>20%) reported a mean score of 4.79, compared to 3.68 for those in the lowest bracket. Given cultural sensitivities around income disclosure in Northern Nigeria, respondents were asked to report income as a percentage category, which preserved data integrity while respecting social norms.

Awareness of CRE technologies was limited: 53.5% reported familiarity, while 46.5% had no prior exposure. Respondents who were aware of CRE reported higher adoption scores (mean = 4.14) than those unaware (mean = 3.73). This finding highlights the importance of information access and public education in enabling energy transitions. Additional breakdowns by awareness, income, and education are provided in Table 2.

The dependent variable, willingness to adopt CRE was measured on a five-point Likert-type scale, reflecting increasing levels of adoption commitment: 1 - Not committed, 2 - Slightly committed, 3 - Moderately committed, 4 - Committed, and 5 - Highly committed. The variable distribution was left-skewed, with over 74.8% of respondents reporting either “Committed” or “Highly committed.” Given its ordinal nature, this outcome was modelled using a MNL approach, which accommodates non-linear relationships and allows comparison across multiple adoption levels.

Descriptive patterns across explanatory variables including education, income, gender, marital status, and household size highlight the multidimensional nature of energy decisions in this context. These baseline insights not only validate the choice of model variables but also inform the interpretation of complex interaction effects explored in later sections.

Table 3-2 thus offers an essential snapshot of respondent characteristics, grounding the inferential analyses in empirical demographic and socioeconomic realities.

3.3.8 Statistical Model Specification

The MNL model was employed to analyze the determinants of household commitment to CRE adoption. This choice reflects the categorical, non-ordered structure of the dependent variable, which captures adoption commitment on a five-point Likert-type scale. Unlike ordered models, the MNL does not assume proportional odds or a strict ranking of outcome categories, making it suitable for contexts where the distances

between categories cannot be meaningfully quantified. Preliminary diagnostic testing confirmed that the proportional odds assumption was violated, reinforcing the appropriateness of the MNL approach [110,134]. The use of MNL in energy adoption research is also consistent with empirical studies in similar settings [135].

In the MNL framework, the probability that household i chooses adoption category j from J unordered alternatives is expressed as:

$$P(Y_i = j | X_i) = \frac{\exp(X_i^\top \beta_j)}{\sum_{k=1}^J \exp(X_i^\top \beta_k)} \quad (3-3)$$

where X_i is a vector of predictor variables for observation i , and β_j is the vector of coefficients for category j relative to the base outcome. In this study, “Not Committed” serves as the reference category. Coefficients are interpreted relative to this base, while average marginal effects (AMEs) are calculated to translate log-odds into more intuitive changes in predicted probability.

To capture both independent and conditional effects, the analysis followed a three-stage estimation strategy. Model 1 estimated the main effects of the core explanatory variables, including socio-structural characteristics (income, education, occupation, demographic controls), socio-cultural factors, perceptual measures, and technological variables. Model 2 introduced interaction terms between awareness and income, and between awareness and education, to examine whether the influence of information access depends on socio-economic position or educational attainment. Model 3 computed AMEs for statistically significant predictors, providing an interpretable measure of their practical influence across the adoption-commitment spectrum.

The AME for a continuous predictor X_q on outcome category j is computed as:

$$AME_{qj} = \frac{1}{N} \sum_{i=1}^N \frac{\partial P(Y_i = j | X_i)}{\partial X_{iq}} \quad (3-4)$$

where N is the number of observations.

Preliminary testing of the proportional odds assumption using the Brant test indicated significant violations ($p < 0.05$), confirming that the ordered logit specification was inappropriate. The MNL specification therefore avoids these restrictions, allowing each adoption category to have its own coefficient vector and improving model fit for the unordered, multi-level outcome. This structured approach allows for a nuanced

interpretation of how household socio-economic resources, informational exposure, and contextual constraints combine to shape CRE adoption behavior. The inclusion of both interaction effects and AMEs ensures that the results speak directly to both statistical significance and policy relevance. The independence of irrelevant alternatives (IIA) assumption was tested using the Hausman–McFadden procedure, confirming model validity, and multicollinearity was assessed via variance inflation factors (VIF), all below the conventional band of 5. The proportional-odds assumption was tested and rejected via the Brant test, motivating the multinomial specification; independence of irrelevant alternatives (IIA) was checked using the Hausman–McFadden test. All estimations were run in STATA 17; full syntax, IIA output, and variance-inflation checks are provided in Supplementary Information (see S2–S3). Complete STATA commands used for model estimation and marginal effects are provided in S1.

3.4 Results and Discussion

This section presents the empirical findings derived from the MNL model applied to assess the determinants of CRE adoption in Northern Nigeria. The results are organized thematically, first detailing inferential outcomes, then examining marginal effects of key variables, and finally conducting diagnostic assessments. These findings are situated within the broader analytical framework and theoretical assumptions established in Section 3.3.6, allowing for context-specific interpretations of adoption behaviors across socio-economic, informational, and institutional lines.

3.4.1 Inferential Analysis

The MNL estimation results identify three predictors as consistently significant in explaining household commitment to CRE adoption in Northern Nigeria: two socio-structural variables (household income and education) and one perceptual factor (prior awareness of CRE). (All coefficients are interpreted relative to the following reference groups: Education—No formal education; Occupation—Unemployed; Income—<5%; Age—18–25; Marital status—Single; Gender—Female; Household size—1–4; Awareness—Not aware). These variables operate both independently and interactively to shape adoption behavior. Income emerged as a powerful determinant (reference = households earning 0–10% of the regional reference income band). Households earning above this baseline were significantly more likely to report higher commitment to adoption. The likelihood increases markedly at the 15–20% and >20%

brackets, with log-odds coefficients of 1.08 and 2.71 respectively (both $p < 0.05$). These results corroborate the theoretical position that financial capacity enhances adoption, not only through affordability but also through increased willingness to make long-term investments in uncertain policy environments [43,136,137].

Awareness of CRE, whether through direct exposure or information channels, also exerts a strong positive influence, particularly among more educated respondents. Higher education (reference = no formal education) independently strengthened comprehension of technical and economic aspects, increasing responsiveness to awareness campaigns. This combination underscores the interplay between structural resources, informational access, and cognitive capacity in shaping CRE adoption pathways.

In interpreting the model, “Not Committed” serves as the base outcome, and comparisons are made against progressively higher levels of commitment. For clarity, categories 4 (“Committed”) and 5 (“Highly Committed”) together represent high adoption, whereas categories 1–3 reflect low to moderate adoption. Table 3-3 presents the parameter estimates from the multinomial logit model, where “Not Committed” serves as the base outcome. Full model outputs (coefficients, standard errors, and test statistics for all categories and specifications) are reported in S2.

Table 3-3. Multinomial logit estimates of CRE adoption.

Variables	Model 1: Main Effects (n = 537); Dependent variable = CRE Adoption	Model 2: Main with interaction effects: Awareness x Education (n = 537); Dependent variable = CRE Adoption	Model 3: Main with interaction effects: Awareness x Income (n = 537); Dependent variable = CRE Adoption
Occupation			
Housing	-2.829* (0.740)	-2.737*** (0.759)	-2.887*** (0.807)
Community	-1.066 (0.856)	-0.926 (0.867)	-1.106 (0.905)
Government	-1.251(0.730)	-1.141 (0.746)	-1.469* (0.790)
Academia	-0.472 (0.820)	-0.368 (0.835)	-0.663 (0.873)
NGO	-1.082 (0.774)	-0.970 (0.788)	-1.367* (0.828)
Health	-1.893 (0.793)	-1.849 (0.803)	-2.069** (0.852)
Local Gov.	-0.673 (0.769)	-0.565 (0.780)	-0.918 (0.831)
Small Scale	-1.242 (0.737)	-1.134 (0.752)	-1.480* (0.805)
Artisan	-1.264 (0.744)	-1.134 (0.764)	-1.455* (0.807)
Farmers	-0.917 (0.730)	-0.770 (0.750)	-1.163 (0.790)
Others	0.873 (-1.098)	-0.932 (0.814)	-1.356 (0.853)
Housing			
Not Committed	(0.014)* [0.027]	(0.014)* [0.027]	(0.012)* [0.023]
Slightly Committed	(0.020)*** [0.069]	(0.020)*** [0.070]	(0.019)*** [0.060]
Moderately Committed	(0.073)*** [0.366]	(0.077)*** [0.358]	(0.077)*** [0.353]
Committed	(0.104) [-0.091]	(0.101) [-0.107]	(0.125) [-0.029]
Highly Committed	(0.143)*** [-0.372]	(0.144)*** [-0.348]	(0.158)*** [-0.408]
Community			
Not Committed	(0.003) [0.003]	(0.003) [0.003]	(0.003) [0.003]
Slightly Committed	(0.009) [0.010]	(0.009) [0.009]	(0.008) [0.009]
Moderately Committed	(0.084) [0.108]	(0.086) [0.096]	(0.077) [0.100]
Committed	(0.088) [0.075]	(0.082) [0.060]	(0.106) [0.102]
Highly Committed	(0.163) [-0.197]	(0.163) [-0.168]	(0.178) [-0.213]
Government			
Not Committed	(0.003) [0.004]	(0.003) [0.004]	(0.003) [0.005]
Slightly Committed	(0.007)* [0.013]	(0.007) [0.013]	(0.007) [0.014]
Moderately Committed	(0.061) [0.133]	(0.065) [0.125]	(0.058)* [0.146]
Committed	(0.088) [0.073]	(0.083) [0.059]	(0.106) [0.105]
Highly Committed	(0.146) [-0.224]	(0.147) [-0.200]	(0.161) [-0.269]
Academia			
Not Committed	(0.002) [0.001]	(0.002) [0.001]	(0.002) [0.001]
Slightly Committed	(0.005) [0.003]	(0.006) [0.003]	(0.005) [0.004]
Moderately Committed	(0.066) [0.040]	(0.071) [0.033]	(0.063)* [0.052]
Committed	(0.095) [0.049]	(0.089) [0.036]	(0.112) [0.076]
Highly Committed	(0.166) [-0.094]	(0.166) [-0.072]	(0.178) [-0.134]
NGO			
Not Committed	(0.003) [0.003]	(0.003) [0.003]	(0.003) [0.004]
Slightly Committed	(0.007) [0.010]	(0.008) [0.010]	(0.008) [0.013]
Moderately Committed	(0.070) [0.111]	(0.073) [0.102]	(0.067) [0.132]
Committed	(0.088) [0.075]	(0.082) [0.060]	(0.106) [0.106]
Highly Committed	(0.152) [-0.199]	(0.152) [-0.175]	(0.165) [-0.255]
Health			
Not Committed	(0.007) [0.010]	(0.008) [0.011]	(0.007) [0.010]
Slightly Committed	(0.014) [0.028]	(0.015) [0.030]	(0.013) [0.028]
Moderately Committed	(0.079) [0.230]	(0.082) [0.230]	(0.076)*** [0.232]
Committed	(0.095) [0.034]	(0.092) [0.013]	(0.111) [0.073]
Highly Committed	(0.149) [-0.302]	(0.148) [-0.284]	(0.163)* [-0.343]
Local Government			
Not Committed	(0.002) [0.002]	(0.002) [0.002]	(0.002) [0.002]

Slightly Committed	(0.005) [0.005]	(0.006) [0.005]	(0.005) [0.007]
Moderately Committed	(0.062) [0.061]	(0.066) [0.053]	(0.059) [0.078]
Committed	(0.090) [0.063]	(0.084) [0.049]	(0.108) [0.094]
Highly Committed	(0.155) [-0.131]	(0.155) [-0.108]	(0.169) [-0.181]
Small Scale			
Not Committed	(0.003) [0.004]	(0.003) [0.004]	(0.003) [0.005]
Slightly Committed	(0.007) [0.013]	(0.007) [0.012]	(0.008)* [0.014]
Moderately Committed	(0.061) [0.132]	(0.065) [0.124]	(0.059)** [0.147]
Committed	(0.088) [0.073]	(0.083) [0.059]	(0.106) [0.105]
Highly Committed	(0.148) [-0.223]	(0.148) [-0.199]	(0.163) [-0.271]
Artisan			
Not Committed	(0.003) [0.004]	(0.003) [0.004]	(0.003) [0.005]
Slightly Committed	(0.008) [0.013]	(0.008) [0.012]	(0.008)* [0.014]
Moderately Committed	(0.062) [0.135]	(0.067) [0.124]	(0.059)* [0.144]
Committed	(0.088) [0.073]	(0.082) [0.059]	(0.106) [0.105]
Highly Committed	(0.149) [-0.226]	(0.150) [-0.199]	(0.163) [-0.267]
Farmers			
Not Committed	(0.002) [0.003]	(0.002) [0.002]	(0.002) [0.003]
Slightly Committed	(0.006) [0.008]	(0.006) [0.007]	(0.006) [0.010]
Moderately Committed	(0.059) [0.090]	(0.063) [0.077]	(0.056)* [0.106]
Committed	(0.088) [0.073]	(0.083) [0.057]	(0.106) [0.104]
Highly Committed	(0.148) [-0.173]	(0.149) [-0.143]	(0.162) [-0.223]
Others			
Not Committed	(0.003) [0.004]	(0.003) [0.003]	(0.003) [0.004]
Slightly Committed	(0.008) [0.011]	(0.008) [0.009]	(0.008) [0.012]
Moderately Committed	(0.071) [0.113]	(0.075) [0.097]	(0.069)* [0.131]
Committed	(0.088) [0.075]	(0.083) [0.060]	(0.106) [0.106]
Highly Committed	(0.155) [-0.202]	(0.157) [-0.169]	(0.168) [-0.253]
Awareness (Yes)			
Not Committed	1.002*** (0.206)	2.181*** (0.767)	1.666*** (0.393)
Slightly Committed	(0.003)*** [-0.006]	(0.003)*** [-0.006]	(0.004)*** [-0.008]
Moderately Committed	(0.007)*** [-0.018]	(0.007)*** [-0.017]	(0.008)*** [-0.021]
Committed	(0.029)** [-0.133]	(0.029)*** [-0.132]	(0.029)*** [-0.144]
Highly Committed	(0.014)*** [0.011]	(0.015)** [0.012]	(0.021)*** [0.046]
	(0.028)*** [0.147]	(0.028)*** [0.144]	(0.028) [0.127]
Income			
Between 5 and 9	0.714*** (0.228)	0.731*** (0.222)	1.350*** (0.376)
Between 10 and 14	0.958 (0.273)	0.945*** (0.267)	1.180*** (0.423)
Between 15 and 20	1.958 (0.655)	2.002*** (0.447)	2.650*** (0.661)
Greater than 20	2.820 (0.655)	2.807*** (0.730)	5.920*** (1.259)
Between 5 and 9			
Not Committed	(0.003) [-0.006]	(0.003) [-0.006]	(0.004) [-0.008]
Slightly Committed	(0.007) [-0.015]	(0.007) [-0.015]	(0.009) [-0.021]
Moderately Committed	(0.034) [-0.102]	(0.034)*** [-0.104]	(0.034) [-0.115]
Committed	(0.016) [0.027]	(0.016)*** [0.027]	(0.026) [0.067]
Highly Committed	(0.029) [0.095]	(0.029)* [0.097]	(0.030) [0.076]
Between 10 and 14			
Not Committed	(0.004) [-0.007]	(0.004)** [-0.007]	(0.005) [-0.008]
Slightly Committed	(0.008) [-0.018]	(0.008)*** [-0.018]	(0.010) [-0.021]
Moderately Committed	(0.037) [-0.132]	(0.037)*** [-0.130]	(0.037)*** [-0.131]
Committed	(0.019) [0.020]	(0.018)*** [0.021]	(0.031) [0.038]
Highly Committed	(0.040) [0.137]	(0.040)*** [0.133]	(0.042)*** [0.123]
Between 15 and 20			
Not Committed	(0.005) [-0.009]	(0.005)* [-0.010]	(0.006)* [-0.011]
Slightly Committed	(0.009) [-0.026]	(0.009) [-0.026]	(0.011)*** [-0.030]
Moderately Committed	(0.042) [-0.219]	(0.041)*** [-0.221]	(0.040)*** [-0.232]
Committed	(0.067) [-0.085]	(0.068)*** [-0.089]	(0.0761) [-0.0538]
Highly Committed	(0.099) [0.339]	(0.099)*** [0.346]	(0.103)*** [0.327]
Greater than 20			
Not Committed	(0.005) [0.339]	(0.005) [-0.010]	(0.006)* [-0.012]

Slightly Committed	(0.010) [-0.029]	(0.010)* [-0.029]	(0.012)*** [-0.033]
Moderately Committed	(0.037) [-0.259]	(0.037)*** [-0.259]	(0.030)*** [-0.287]
Committed	(0.102) [-0.224]	(0.102)*** [-0.217]	(0.060)*** [-0.362]
Highly Committed	(0.125) [0.521]	(0.125)*** [0.515]	(0.067)*** [0.694]
Awareness X Education			
Yes X Primary		-1.749* (0.975)	
Yes X Masters		-1.911* (1.066)	
Awareness X Income			
Yes X Between 5 and 9			0.463* (-1.127)
Yes X Greater than 20			-3.650*** (1.388)
Model Fit Statistics			
	Log pseudolikelihood = -528.886	Log pseudolikelihood = -527.153	Log pseudolikelihood = -524.603
	Pseudo R2 = 0.127	Pseudo R2 = 0.130	Pseudo R2 = 0.134
	Wald chi2(45) = 201.31	Wald chi2(45) = 228.11	Wald chi2(45) = 384.51

*Note: Reported entries are coefficients. Heteroskedasticity-robust standard errors are in parentheses (); average marginal effects (AMEs) are in square brackets []. ***p < 0.01, **p < 0.05, *p < 0.10. As a sensitivity check, models with SEs clustered by LGA yield unchanged inference (see Supplementary S1/S2).*

Awareness of renewable energy projects or technologies was also highly significant ($p < 0.01$) in predicting higher adoption categories. Respondents with prior exposure to CRE were far more likely to fall in the “Highly Committed” category. This validates the role of informational asymmetry in shaping energy decisions, particularly in regions where community-level awareness campaigns are sparse or inconsistent [138–141]. Importantly, interaction effects reveal that awareness amplifies the influence of both income and education, supporting the non-linear socio-structural framework proposed in this study.

Occupation played a nuanced role. Compared to the unemployed reference group, individuals in farming, civil service, and small-scale trading showed significantly higher odds of adoption. Civil servants and NGO workers, in particular, demonstrated stronger commitment (log-odds > 0.9), likely due to stable income streams and greater exposure to institutional and policy knowledge [142,143]. By contrast, those in informal sectors such as artisans and small-scale traders displayed lower probabilities, suggesting they may be underserved by formal energy programmes.

Education was positively associated with CRE adoption across all levels. Respondents with tertiary and postgraduate education were significantly more likely to be “Highly Committed” than those with no formal education. This reinforces findings that educational attainment enhances environmental awareness, risk mitigation capacity, and openness to innovation [138,144,145]. Interestingly, even religious schooling, often overlooked in prior research, showed a mild positive correlation with moderate

commitment levels, reflecting the role of trust-based community education in disseminating information.

Gender and marital status exhibited mixed but policy-relevant effects. While males had slightly higher odds of adoption, the difference was not statistically significant, suggesting that gender is not a primary driver once structural variables are accounted for. However, widowed respondents, though a small subgroup showed disproportionately high commitment levels, possibly due to sole household responsibility and stronger incentives for energy self-sufficiency.

Age followed a non-linear pattern. Respondents aged 26–45 were significantly more likely to adopt CRE than both younger (18–25) and older (>55) cohorts. This suggests a middle-age effect, where financial responsibility, awareness, and decision-making power converge [146,147]. Household size also mattered: larger households (≥ 5 members) displayed higher commitment, likely reflecting greater energy needs and economic pressure to seek reliable solutions.

Taken together, these findings validate the socio-structural framework proposed in this study and affirm the use of an interaction-augmented MNL model. Adoption is not determined solely by affordability or technology availability but rather emerges from layered social realities. The results highlight income, education, and awareness as critical drivers, while occupation, age, household structure, and marital status provide additional nuance. This comprehensive perspective underscores the need for equity-sensitive, context-specific interventions when designing policies to scale CRE in SSA.

3.4.1.1 Marginal Effect of Awareness on High Adoption

To assess how informational exposure influences CRE adoption, we compute the average marginal effects (AME) of awareness across commitment levels. Awareness was measured as a binary variable (1 = yes, 0 = no), indicating whether respondents had prior exposure to renewable energy technologies or community projects. Its inclusion in Models 2 and 3 (Table 3-3) allows us to explore both its direct effects and interaction with structural factors like income and education.

The marginal effect of awareness on the probability of being “Highly Committed” to CRE adoption is substantial and statistically significant across all three models. Specifically, in Model 1, awareness increases the probability of high commitment by 14.7 percentage points (AME = 0.147, $p < 0.01$). In Model 2, where awareness

interacts with education, the marginal effect remains positive and robust ($AME = 0.144$), though slightly reduced. Model 3, which introduces awareness-income interactions, also sustains this effect ($AME = 0.127$), affirming that informational exposure independently elevates commitment levels regardless of economic status.

These findings confirm the hypothesis that awareness serves not only as a direct enabler of adoption but also as a conditional amplifier of socioeconomic capacity [88,105,106,112]. Put differently, the marginal utility of awareness is higher when individuals already possess education or income to act on that information [148–150]. This supports the framework introduced in Section 3.3.6, which proposed a non-linear and interactional view of adoption behavior.

Moreover, the steep rise in probability for high commitment among aware individuals, particularly in lower-income and moderately educated groups highlights the equity-enhancing role of awareness. In under-resourced communities where affordability and infrastructure access are constrained, informational access functions as a quasi-structural equalizer, bridging gaps that income alone may not close [107,141]. Marginal probabilities and conditional AMEs underlying Figure 3.3 are reported in S3.

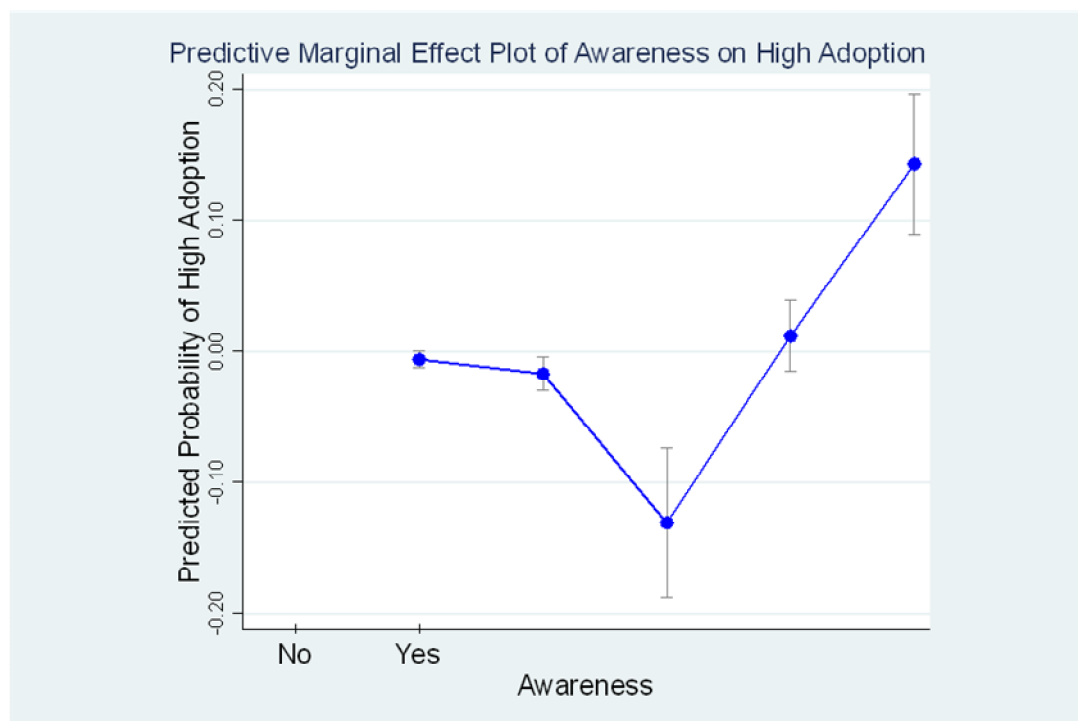


Figure 3-3. Predictive Marginal Effect Plot of Awareness on High Adoption.

Figure 3-3 visually reinforces this interpretation, showing a marked increase in the predicted probability of high CRE adoption among respondents who reported prior awareness. The slope between the “No” and “Yes” awareness categories is pronounced, and the tight confidence intervals further underscore the robustness of this relationship. This visual evidence confirms that awareness materially shifts adoption probabilities, validating the quantitative outputs of the MNL model.

These findings also align with previous empirical work across SSA, where CRE adoption was significantly improved by grassroots awareness campaigns and NGO-led sensitization efforts [104,105,108]. Awareness does not operate in isolation; rather, it translates latent potential into tangible commitment when coupled with enabling conditions.

Taken together, this analysis underscores the policy-critical insight that awareness interventions especially if localized, culturally sensitive, and community-trusted can yield disproportionately large gains in renewable energy commitment. Subsequent sections extend this insight by showing how awareness further interacts with income (3.4.1.2) and occupation (3.4.1.3) to shape the adoption gradient.

3.4.1.2 Marginal Effect of Income on High Adoption

To further interrogate how structural capacity shapes renewable energy commitment, we examined the marginal effects of income across adoption levels. Income was treated as a categorical variable based on respondents’ positioning relative to the regional income bands: 5–9%, 10–14%, 15–20%, and >20%. These brackets were developed to reflect locally meaningful bands in Northern Nigeria, bypassing conventional but often culturally insensitive income banding [130,151].

Results from the marginal effects analysis (derived from Models 2 and 3 in Table 3-3) show a clear, positive, and monotonic relationship between rising income levels and the probability of being “Highly Committed” to CRE adoption. For instance, respondents earning 15–20% above the reference band exhibited a 33.9 percentage point increase in the likelihood of high commitment (AME = 0.339), while those earning above 20% saw this probability rise to 52.1 percentage points (AME = 0.521), both significant at $p < 0.01$.

These findings validate the core analytical assumption that material capacity is central to technology uptake in low-resource settings. In Northern Nigeria, income serves not

just as a marker of affordability, but as an indicator of risk tolerance, access to financing, and long-term planning capacity, all of which are essential for CRE investment [114,131].

This pattern is illustrated in Figure 3-4, which presents the predicted marginal effect plot of income on the probability of high CRE adoption. The curve reveals a steep increase in predicted probability across income brackets, with notably wider confidence intervals at the lower-income end, indicating higher response variability in these segments.

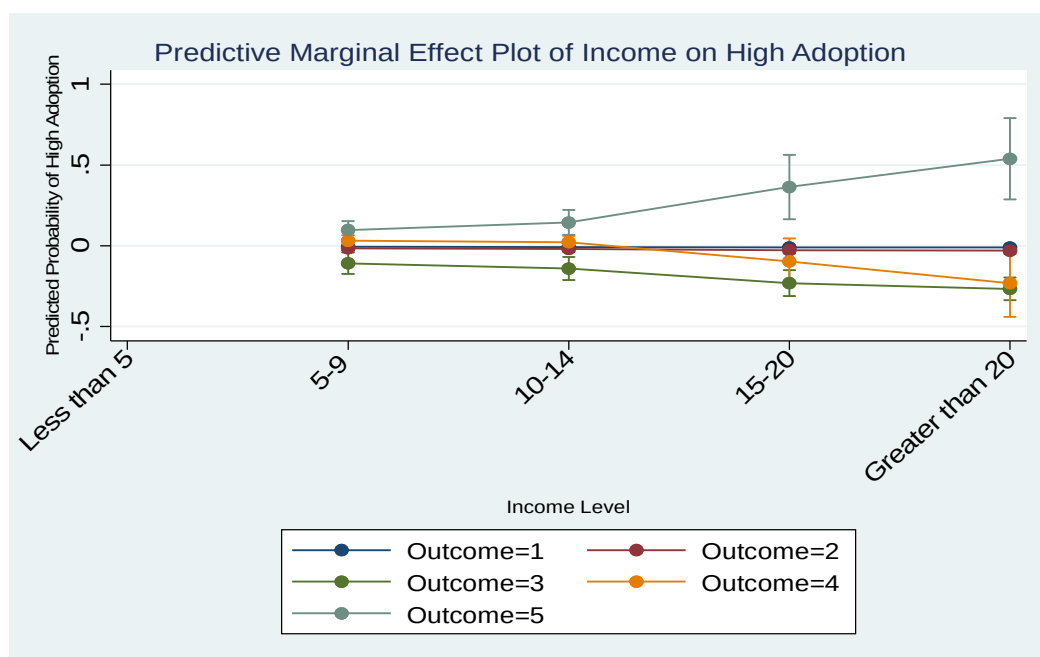


Figure 3-4. Predicted probability of high CRE adoption across income levels, based on marginal effects from Model 3.

The non-linearity captured here reveals important insights. While all income brackets above 10% positively influence adoption, the most dramatic jump occurs between the 15–20% and >20% groups, suggesting that band effects may be at play. In other words, once basic economic security is achieved, the likelihood of adopting sustainable energy solutions escalates significantly. These dynamics echo previous studies that highlight income as a tipping point factor in energy transitions, especially in informal economies with weak credit infrastructure [129,147].

Interestingly, interaction effects between income and awareness reveal diminishing marginal influence of awareness at higher income levels. For instance, in Model 3, the awareness-income interaction for the >20% group was negative and significant

(-0.365, $p < 0.01$), implying that once households attain economic capability, additional awareness campaigns may yield diminishing returns. This supports the study's broader argument that awareness is most effective among lower-income households, where it acts as a structural equalizer [141,152].

Taken together, these findings strengthen the theoretical claim that CRE adoption is mediated by a layered interaction between structure (income), cognition (awareness), and socio-economic identity. Policy frameworks must therefore embrace targeted and stratified interventions, combining financial incentives for low-income groups with informational campaigns tailored to cultural and economic realities. Average marginal effects by income band and associated plots (Figure 3-4) are provided in S2–S3.

3.4.1.3 Marginal Effect of Occupation on High Adoption

Occupation emerged as a nuanced but statistically significant determinant of high CRE adoption, reflecting not only income regularity but also informational access, job security, and social capital. The marginal effects derived from Model 3 indicate that individuals employed in the civil service, NGOs, and small-scale businesses are substantially more likely to report high commitment to CRE adoption compared to the unemployed reference group.

Specifically, civil servants exhibit a 13.1 percentage point higher probability of falling in the “Highly Committed” category ($AME = 0.131$, $p < 0.05$), while NGO workers demonstrate a marginal effect of 11.4 percentage points ($AME = 0.114$, $p < 0.05$). Artisans and traders also show elevated probabilities, though at slightly lower magnitudes, consistent with their variable income streams and partial exposure to market-based energy solutions. In contrast, subsistence farmers and informal workers show only marginal increases or statistically insignificant effects, underscoring the stratified nature of occupational influence.

These findings validate the theoretical claim that economic identity beyond income brackets shapes energy behavior. Employment in institutionalized sectors such as civil service or NGOs not only implies financial stability but also facilitates access to energy policy discourses, peer learning, and credibility of information sources [104,142]. Occupation, in this context, functions as a proxy for both structural advantage and informational bandwidth.

This pattern is visually confirmed in Figure 3-5, which plots the predicted probabilities of high CRE commitment across occupational categories. The steepest slope is observed among civil servants and NGO staff, while flatter gradients characterize informal, agricultural, or unemployed respondents. This visualization reinforces that certain occupations confer both economic security and greater exposure to institutional narratives around clean energy transitions.

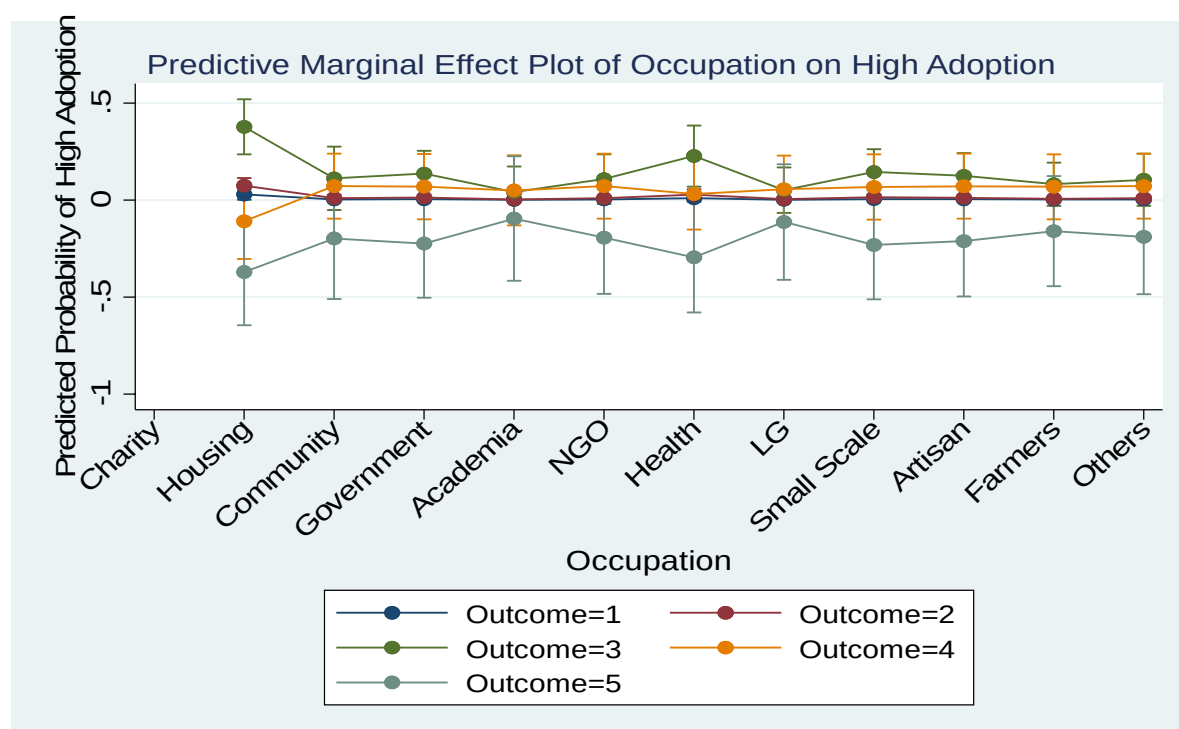


Figure 3-5: Predicted probability of high CRE adoption across occupational categories, based on marginal effects from Model 3.

These insights strengthen the study's argument that structural embeddedness via occupation, income, and awareness is central to renewable energy behavior in marginalized communities. The policy implication is that occupation-sensitive outreach strategies (e.g., workplace-targeted energy literacy programmes) could significantly amplify CRE adoption, especially when tailored to sectors with latent influence but informational gaps.

3.4.2 Interaction Effects

To deepen the analysis of how informational access conditions structural factors in renewable energy adoption, two interaction terms were tested in Models 2 and 3 of the MNL framework: awareness $\times$ education and awareness $\times$ income. These interactions allow us to move beyond the additive influence of individual variables and

probe whether informational exposure acts as an enabler or constraint moderator in contexts of differing socioeconomic capacity.

The awareness $\times$ education interaction reveals that the effect of awareness on CRE commitment is not uniform across educational levels. While awareness alone increases the probability of high adoption (as shown in Section 3.4.1.1), this effect is significantly attenuated among respondents with only primary or master's-level education. For instance, the coefficient for awareness $\times$ primary is -1.749 ($p < 0.1$), and for awareness $\times$ master's, -1.911 ($p < 0.1$), suggesting that the informational benefits are diminished in these groups. This pattern implies that awareness requires cognitive scaffolding either foundational literacy or higher-level analytical ability to translate into actionable adoption behavior. It also highlights a key policy nuance: awareness campaigns must be tailored to match the educational profile of target communities, especially in settings where generic messaging fails to reach or resonate effectively.

The second interaction, awareness $\times$ income, produced a mixed pattern. For respondents in the middle-income category (5–9% above regional bands), awareness amplified commitment levels, with a positive and statistically significant interaction term ($\beta = 0.463$, $p < 0.1$). This confirms the hypothesis that awareness has higher marginal utility when economic means exist to act on the information, reinforcing the idea that informational asymmetries function not in isolation but in synergy with affordability. However, at the highest income tier (>40%), the interaction effect turns negative ($\beta = -3.650$, $p < 0.01$). This suggests that among the wealthiest respondents, awareness may play a diminishing or even contradictory role, possibly because high-income individuals already possess alternative energy pathways (e.g., diesel generators, private solar installations) and are thus less influenced by community-level awareness messaging. It may also reflect information fatigue or mistrust, especially where prior energy interventions were poorly executed or politicized.

Together, these interaction effects affirm the study's core theoretical claim: adoption behaviors in SSA are conditioned by non-linear socio-structural dynamics, where awareness mediates but does not override the constraints and capacities shaped by income and education. These findings provide critical empirical support for designing more nuanced, equity-sensitive policy interventions in future CRE programs.

3.4.3 Estimation Diagnostics and Model Robustness

To ensure the validity and interpretive confidence of the MNL model employed in this study, several diagnostic checks and robustness evaluations were conducted. These assessments not only serve to confirm the internal consistency of the model but also help to situate its results within the broader analytical framework proposed in Section 3.3.6, particularly given the study's emphasis on non-linear, interactional dynamics in CRE adoption behavior.

The overall fit of the model is acceptable and consistent with expectations for behavioral choice models in social science research. Across the three model specifications—baseline, interaction with education, and interaction with income—the McFadden pseudo R^2 values ranged from 0.127 to 0.134. While pseudo R^2 values in discrete choice models do not have a direct interpretation analogous to R^2 in OLS regressions, values in this range are widely considered reasonable in adoption and behavioral studies, especially in contexts where decisions are influenced by complex social, cultural, and economic variables. In addition, the Wald chi-squared statistics for all three models were statistically significant at the 1% level, indicating that the explanatory variables jointly have a non-random influence on the probability of belonging to a particular CRE adoption category.

Furthermore, concerns about multicollinearity were addressed through a post-estimation Variance Inflation Factor (VIF) analysis. All VIF values fell below the conventional bands of 5, suggesting that the independent variables do not suffer from high intercorrelation. This confirms that the explanatory power attributed to income, occupation, awareness, and education arises from distinct and meaningful contributions of each variable, rather than overlapping variance.

To evaluate whether the core assumption of the MNL model—the Independence of Irrelevant Alternatives (IIA)—held in this context, the Hausman-McFadden test was conducted. The test failed to reject the null hypothesis, indicating that the assumption of independence across outcome categories was not violated. This suggests that the inclusion or exclusion of any particular adoption category does not systematically distort the relative probabilities associated with the remaining categories, lending confidence to the model's internal structure.

Predictive power was assessed by comparing predicted probabilities against actual adoption categories. The model performed notably well in distinguishing between lower and higher levels of commitment. Specifically, it demonstrated stronger predictive accuracy for the “Moderately Committed” and “Highly Committed” categories—those of greatest policy relevance. This pattern suggests that socio-structural and informational predictors become more salient as respondents move from passive to active CRE adoption intent, reinforcing the argument that adoption deepens not only with access and affordability but also with trust, capacity, and awareness.

Additional sensitivity checks were performed to assess robustness under varying specifications. We also estimated models with standard errors clustered at the LGA level; coefficients and AMEs remained within the 95% confidence intervals (CIs) of the robust specification, and substantive conclusions were unchanged. We also tested potential interviewer effects by adding interviewer indicators to the MNL and running a joint Wald test; the test was not significant, coefficients and AMEs were stable, and inference matched models with SEs clustered by interviewer. First, because of sparse counts in the “Slightly Committed” category, we tested collapsed outcome groupings to avoid overfitting and improve estimate stability; results did not materially change. Second, we re-estimated using alternative reference categories (e.g., “Slightly Committed” instead of “Not Committed”); core findings were unchanged. Finally, subsample estimations by gender and location (urban vs. semi-urban) probed heterogeneity; while some coefficients lost significance due to smaller *n*, directional patterns persisted across subgroups.

Taken together again, these diagnostics and robustness checks reinforce the methodological soundness of the MNL approach adopted in this study. The model performs credibly both in statistical terms and in its alignment with the theoretical underpinnings of adoption behavior in marginalized communities. By demonstrating strong internal consistency, predictive validity, and sensitivity to structural interactions, the estimation results provide a reliable empirical foundation for the policy discussions that follow in the concluding section.

In summary, the empirical results demonstrate that CRE adoption in Nigeria is strongly influenced by a combination of structural socioeconomic variables, informational

exposure, and their interaction. The model performs robustly across diagnostic checks and confirms the validity of the study's socio-structural analytical framework. These insights establish a strong empirical basis for the next section, which presents context-specific policy recommendations and highlights how these findings can inform inclusive and evidence-driven energy governance across emerging economies. Model-fit metrics, classification accuracy, and additional robustness checks are compiled in Supplementary Information (see SI1–SI3).

3.5. Conclusion and Policy Implications

This study has provided a nuanced and empirically grounded account of the determinants influencing CRE adoption in Northern Nigeria. Using an interaction-augmented MNL model, the analysis shows that adoption behavior is shaped not only by affordability or technological availability, but also by the interplay between socio-economic status, informational access, and institutional exposure. Income, awareness, and education emerged as the most statistically significant predictors of higher adoption commitment, with occupation and household size exerting additional but secondary influence.

The findings demonstrate that energy transition policy cannot rely on one-size-fits-all instruments. Financial incentives alone are unlikely to suffice unless coupled with awareness campaigns and trust-building mechanisms [153]. The differentiated effect of income, particularly at bands beyond 15% and 20% of regional averages, supports the use of relative income proxies in targeting subsidies or investment programmes [102,154,155]. This approach is especially pertinent in contexts where direct income reporting is culturally sensitive or impractical, as in rural and peri-urban Northern Nigeria.

Awareness, by contrast, emerged as a low-cost, high-impact lever. Its direct and interactive effects suggest that information is not a secondary add-on but a central policy driver. Awareness campaigns, when tailored to informal economies and local communication systems, can generate outsized adoption effects at relatively low cost. Policies that leverage radio broadcasts [156], faith-based networks [157], and cooperative societies [158] could deliver significant behavioral change while simultaneously building trust in institutions [103–105]. This points to a strategic trade-

off: while financial interventions are resource-intensive, informational interventions can stretch limited budgets further, especially in low-resource settings.

The differentiated influence of occupational categories also matters for design. Civil servants and NGO workers exhibited higher adoption likelihoods, likely due to stable income and institutional exposure, whereas artisans and small-scale traders showed systematically lower probabilities [142,143]. Current CRE programmes risk entrenching inequality if they remain biased toward formal-sector households. Micro-financing schemes, pay-as-you-go models, and group-based lending could bridge this divide, enabling informal-sector actors to participate [159,160]. For artisans and traders who rely on irregular income streams, flexible financing mechanisms will be critical.

Education reinforces this stratification. The interaction effects between education and awareness demonstrate that households with higher education levels are more responsive to information interventions, while lower-educated households may require more intensive, trust-based communication. Beyond short-term campaigns, embedding renewable energy literacy into curricula, vocational training, and agricultural extension services would gradually democratize information access and reduce asymmetries [107,148]. Over the long run, this also supports behavioral durability, ensuring adoption commitments are sustained rather than short-lived.

Household size, although a secondary determinant, points to equity implications. Larger households often face compounded affordability and information challenges, particularly where dependency ratios are high. Targeted subsidies for large families, or community-pooled financing structures, could prevent exclusion. This nuance underscores the need for policies that are not only efficient but also distributive in intent.

The broader lesson is that advancing CRE in Northern Nigeria and similar contexts across SSA requires policy portfolios rather than isolated instruments. Technical fixes or blanket subsidies cannot substitute for strategies that are socially embedded, economically adaptive, and institutionally legitimate. Awareness, income-sensitive financing, and occupational targeting must be deployed in combination. Moreover, governance credibility matters: without trust in delivery institutions, even well-designed programmes may falter.

Although this analysis is rooted in Northern Nigeria, its implications resonate across SSA and other low-resource, high-need regions. Transferability demands adaptive localization rather than wholesale replication. For fragile states and underserved regions facing persistent energy poverty, the use of relative income bands, interaction-sensitive modelling, and trust-mediated information campaigns offers a robust evidence base for equitable energy transition policies [20,25,43]. In doing so, this study adds to the wider discourse on energy justice and just transitions, highlighting that the social architecture of adoption is as decisive as the technical design of systems [161–163].

In sum, community renewable energy in Nigeria will not succeed through technological diffusion alone. It requires policies attuned to the lived realities of marginalized communities, sensitive to economic identity, and responsive to informational legitimacy. By moving beyond techno-economic determinism and acknowledging the interplay of structure, agency, and trust, this paper contributes both to the empirical understanding of CRE adoption and to actionable policy frameworks for socially grounded energy transitions in SSA.

For policy transferability, the lesson is clear, CRE adoption strategies in SSA must balance universal structural drivers (income, education, household size) with careful adaptation to local socio-political realities. Northern Nigeria's case illustrates how region-specific factors such as ethno-religious networks, community trust, and historical governance legacies shape adoption uniquely. Recognizing what is generalizable and what is context-bound is therefore essential to designing interventions that are both equitable and effective.

3.5.1 Limitations and Directions for Future Research

While this study provides novel empirical insights into the socio-structural determinants of CRE adoption in Northern Nigeria, certain limitations should be acknowledged. First, although the use of relative income proxies enhanced data reliability, it may still obscure intra-category heterogeneity in financial behavior or energy decision-making power. Second, the cross-sectional survey design limits causal inference; longitudinal data could enrich understanding of how commitment levels evolve over time or in response to policy shocks. Third, the interaction effects, though insightful, are based on categorical constructs which may benefit from further

disaggregation in future studies, particularly regarding gendered labor roles or informal educational exposure. Lastly, the study focused on behavioral intention rather than actual adoption outcomes, a distinction that future mixed-method or panel studies could help to bridge. Nonetheless, the methodological approach, coding innovations, and localized framing presented here offer a replicable model for energy research that is grounded in social realities and responsive to community agency.

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4 INNOVATIVE DECENTRALIZED GOVERNANCE FOR RENEWABLE ENERGY TRANSITIONS: EMPOWERING LOCAL COMMUNITIES IN NIGERIA⁷

**Kim Kaze; Elisabeth Shrimpton; Nazmiye Balta-Ozkan.*

Abstract

Energy poverty remains a critical challenge in Nigeria, despite significant investments and a wealth of abundant natural resources. Centralized energy governance structures have struggled to address the nuanced needs of local communities, particularly in underserved rural areas. This study explores the transformative potential of decentralized governance in advancing community renewable energy (CRE), with a specific focus on the role of local governments. Through a qualitative analysis of semi-structured interviews with fifteen key stakeholders in Nigeria's energy sector, the paper advocates a Community Renewable Energy–Multi-Level Governance (CRE-MLG) framework. Findings underscore the critical importance of local governments in fostering awareness, securing investments, and enabling sustainable energy solutions tailored to regional needs. Central to this framework is the introduction of Renewable Energy Desk Officers within local governments to facilitate coordination, enhance coordination, deepen community engagement, and bridge the gap between national policies and grassroots implementation. Additionally, the study identifies key enablers, such as innovative funding mechanisms, supportive policies, and institutional coordination, as critical for the success of CRE projects. This paper contributes to the discourse on energy transitions in Sub-Saharan Africa by presenting a scalable governance model that aligns with Nigeria's climate goals and Sustainable Development Goal 7 (SDG7). While country-specific, these insights may inform parts of Sub-Saharan Africa where institutional conditions are comparable; transferability should be established empirically. The proposed framework offers actionable insights for policymakers and practitioners aiming to address energy poverty and foster sustainable development through inclusive, community-driven renewable energy solutions.

Keywords: Community Renewable Energy, Multi-Level Governance, Renewable Energy Desk Officers (REDOs), Sustainable Development Goal 7 (SDG7), Local Government, Energy Transitions, sub-Saharan Africa

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4.1 Introduction

Access to reliable and affordable energy remains a formidable challenge in sub-Saharan Africa (SSA) [1,2], where over 51% of the people still lack electricity despite decades of investments and policy interventions [3]. Nowhere is this disparity more evident than in Nigeria, where energy poverty continues to undermine economic growth and human development [4,5]. Achieving universal energy access by 2030—a central goal of Sustainable Development Goal 7 (SDG-7) [1,6]—requires addressing deeply rooted barriers, including inadequate financing, infrastructural deficits, and fragmented governance systems [2,7,8]. Furthermore, the energy transition intersects with broader Sustainable Development Goals (SDGs), such as SDG 13 (Climate Action) and SDG 10 (reduced inequalities), emphasizing the need for equitable and inclusive solutions [9,10]. Current projections paint a stark picture: SSA's electrification rate is expected to stagnate at only 30% by 2030—far below the threshold needed to alleviate energy poverty and drive transformative development [10–12]. With an estimated \$20 billion required annually to bridge this gap [13], the urgency for innovative governance frameworks and community-driven energy solutions has never been greater. While country-specific, these insights may inform parts of SSA where institutional conditions are comparable; transferability should be established empirically.

The headline, “Nigeria’s Power Grid Collapses for 11th Time in 2024” [14,15], starkly illustrates the consequences of a failing energy system. Repeated grid collapses reflect deep structural weaknesses, policy misalignments, and a critical gap in ensuring reliability and resilience [16–20]. If the most populous country in SSA faces such chronic instability, it raises an urgent question: How can sustainable and inclusive energy governance be realized in a region where even foundational energy systems falter?

The persistence of energy poverty in Nigeria, despite substantial investments, highlights a critical disconnect between centralized governance structures and the specific energy needs of local communities [21,22]. Centralized systems frequently disregard the socio-economic and cultural contexts of affected regions, resulting in policies that fail to address the nuanced challenges of energy poverty [21,23]. This disconnect is exacerbated by limited public participation and a lack of accountability in

energy decision-making processes, which are essential for developing effective strategies to alleviate energy poverty [24,25].

The current energy governance system in Nigeria operates a top-down, centralized structure that has, over several decades, failed to address the country's extensive energy poverty [26–28]. Despite decades of substantial financial investments in this centralized structure the majority of Nigeria's population remains unconnected to the grid, limiting socio-economic development opportunities and underscoring the inadequacies of the existing system [26]. Thus, energy poverty, a critical barrier to sustainable development, affects over 75% of the population [29]. This challenge is especially severe in rural areas, where only about 10% of the population has access to electricity, highlighting a substantial gap in electrification efforts [30]. The Northeast region exemplifies this crisis, with 98.7% of its population living below the energy poverty line, marking it as the area with the highest level of multidimensional energy poverty in the country [31]. These statistics further reveal the pressing need for inclusive and targeted interventions to bridge the wide access gap.

Community renewable energy (CRE) offers a potential solution to address current systemic failures. By integrating citizens and community perspectives into energy decision-making, CRE may enhance the relevance, inclusivity, and acceptance of energy policies [32–34]. Involving citizens in planning and implementation aligns energy solutions with local contexts, improving both legitimacy and sustainability [35]. This participatory approach has demonstrated effectiveness in bridging gaps between policy aspirations and on-ground realities. Yet, despite its promise, the evaluation of energy governance—particularly in SSA—remains underexplored [36].

In addition, community-driven initiatives present a promising alternative by directly engaging local communities and customizing solutions to meet their unique needs [37,38]. Unlike top-down approaches, these initiatives can bridge the gap by fostering active local involvement, which helps tailor interventions to regional contexts. By integrating local insights, community-led energy projects offer a more context-sensitive and responsive approach to energy poverty alleviation, making them potentially more effective than centralized strategies in addressing the specific challenges faced by diverse communities [37,39].

Further, to mitigate energy shortage, citizens have resorted to self-help and increasingly rely on hydrocarbon-powered generators as alternative energy sources to sustain their households, small businesses, and economic activities [40]. To illustrate the scale of this issue, recent figures indicate that Nigerians collectively expended approximately \$11.9 billion in 2023 on petrol- and diesel-powered generators, primarily to meet household and small business energy demands (Addeh 2024)—This level of expenditure represents a substantial economic burden on citizens and highlights the inefficiencies of continued reliance on fossil-based self-generation. Redirecting such financial resources toward cleaner alternatives, such as CRE, could significantly advance Nigeria's energy transition objectives and promote more sustainable, cost-effective energy access in the long term.

Despite the common perception that renewable energy (RE) is prohibitively expensive, the billions of dollars spent annually by citizens on procuring and operating hydrocarbon-powered generators [41–46] highlight a significant opportunity for decentralized, community-driven clean energy solutions. This transition holds the potential to alleviate the financial burden on households while simultaneously empowering communities to take ownership of their energy resources, effectively returning power to the people. Renewable energy, as the most sustainable alternative, offers far-reaching advantages, including improved public health by reducing pollution-related illnesses [47], enhanced environmental preservation [48] through reduced carbon emissions, and greater energy security by diversifying energy sources and reducing dependence on volatile fossil fuel markets [49].

While the potential for CRE adoption in Nigeria is promising given the country's abundant natural resources and the global shift towards sustainable energy, coordinated implementation remains a critical need. A multi-level governance (MLG) approach may offer a robust platform to facilitate energy transition in Nigeria by integrating diverse governance levels and stakeholders, thereby addressing complex challenges associated with energy policy and implementation [50,51]. MLG allows for the coordination of policies across different governance levels, from local to international, and involves various stakeholders, including governments, private sectors, and civil society, which is crucial for effective energy transition [51].

This paper explores the potential of local governments taking on expanded roles and responsibilities, serving as the critical link between communities and the broader energy governance framework of the federal government. The CRE-MLG framework conceptualized here explores local governments as linchpins for facilitating CRE initiatives, promoting sustainable energy solutions tailored to community needs, given their unique position as the closest tier of government to the communities they serve. This proximity enables local governments to better understand the socio-economic realities, cultural contexts, and energy demands of their constituencies, positioning them as critical actors in bridging the gap between centralized policies and grassroots implementation. Through a qualitative analysis of semi-structured interviews of 15 state and non-state actors in the Nigerian energy supply industry, we also consider a CRE-MLG framework, and how a decentralized, community-centered governance structure can effectively advance RE adoption and foster a more inclusive, resilient energy system for Nigeria.

To summarize, Nigeria has made strides in its energy sector, a significant portion of the population, particularly in rural communities, still lacks access to reliable electricity [10,52]. CRE may present a viable solution to bridge this energy gap and empower local communities. However, successful CRE implementation hinges on a robust and supportive governance framework that effectively connects communities with all tiers of government. Therefore, this research focuses on two main questions:

1. To what extent can Nigeria's current energy governance framework be adapted to stimulate and support Community Renewable Energy (CRE) adoption?
2. How can local governments (LGs) be supported in effectively connecting communities with other tiers of government when implementing Community Renewable Energy (CRE) in Nigeria

The structure of this paper is organized as follows: Section 4.2 presents a comprehensive overview of the foundational concepts and situates these within the context of Nigeria's energy landscape. Section 4.3 details the research methodology adopted for this study which consists of semi-structured interviews with fifteen (15) experienced state and non-state actors, key players within the Nigerian energy supply industry, followed by section 4.4, which presents the thematic findings. Section 4.5 provides a discussion of the results. Lastly, section 6 offers concluding insights,

highlighting key findings and providing recommendations for policy implications and directions for future research.

4.2 Theoretical Foundations and Conceptual Analysis

4.2.1 Foundation of Community Renewable Energy (CRE)

The foundations of community renewable energy are built upon a high degree of citizen agency and direct involvement in the ownership, management and benefits of projects [53]. CRE has emerged as a response to the demand for sustainable energy and is characterized by the active participation and ownership of local communities [53,54]. Historically, CRE initiatives have gained traction in several countries, notably the Netherlands, Germany, and Denmark, all in the Global North. In the Netherlands, wind cooperatives have operated since the 1980s; in Germany, community energy projects have roots reaching back over a century; and Denmark's community-based district heating systems, developed in response to the oil crisis of the 1970s, underscore the long-standing tradition of community energy [34]. This historical context highlights the potential role of local involvement in driving the energy transition, underscoring community engagement as a catalyst for accelerating renewable energy adoption [55].

Moreover, the appeal and effectiveness of CRE stem from a diverse set of motivations. CRE projects bring together citizens, social entrepreneurs, and local authorities who collectively invest in, produce, and consume renewable energy, adding a local dimension to the global fight against climate change [56]. These initiatives can foster regional economic growth and encourage social acceptance of renewable technologies [57]. Evidence shows that community ownership of renewable energy projects can have notable economic impacts by boosting local economies, strengthening community resilience, and enhancing residents' sense of belonging [58]. Such projects often contribute to job creation, infrastructure improvements, and increased awareness of sustainable practices, all of which are essential to generating and maintaining public support [59,60].

In addition to economic motivations, regulatory and policy environments play a pivotal role in facilitating the growth and stability of CRE. Supportive legal frameworks have transformed grassroots efforts into widely recognized components of mainstream energy solutions, as exemplified by various European countries [61]. These

frameworks address challenges specific to community energy projects, such as financing obstacles and regulatory barriers, thereby enabling communities to effectively leverage renewable energy resources [62]. Furthermore, integration with local governance structures is critical for ensuring that CRE align with broader energy policies and address local needs [63]. For instance, the European Union's Renewable Energy Directive (RED II) underscores the critical role of energy communities in the shift to sustainable energy, offering a comprehensive policy framework to support their development [64].

Finally, social dynamics play a critical role in the success of CRE. Elements such as social norms, trust, and community identity profoundly influence public acceptance and the effective deployment of CRE [65]. Actively involving local communities in both the planning and implementation phases of energy initiatives can build a strong sense of ownership and responsibility, which is needed for the long-term sustainability of CRE projects [66]. The integration of local cultural values and traditional knowledge into the management of renewable resources enhances community engagement and promotes the development of innovative, locally tailored solutions [67]. Evidence consistently shows that renewable energy achieves higher levels of social acceptance when local populations are meaningfully involved in decision-making processes [68].

4.2.2 Theoretical Perspective of Multi-Level Governance

The concept of multi-level governance (MLG) underscores the decentralization of authority from central states to various governance levels, addressing the limitations of state-centric models. MLG highlights the interdependencies between governance tiers and the expanding role of non-state actors, necessitating a nuanced understanding of shared responsibilities in decision-making processes [69]. This framework is particularly relevant to the energy sector, where governance intersects with global challenges such as climate change mitigation, equitable energy access, and pollution reduction [70].

Energy governance operates across local, national, and global scales, requiring coordination beyond individual jurisdictions to balance state authority with societal participation. A multi-level framework harmonizes policies across governance tiers, ensuring energy solutions are both inclusive and context-sensitive [71,72]. Addressing these complexities demands a shift toward decentralized solutions and reimagined

energy infrastructures that align with local socio-techno-economic realities [73–75]. By fostering integration across governance levels, MLG has the potential to provide a robust foundation for advancing sustainable energy transitions and promoting energy justice.

Operationalizing Multi-Level Governance in Energy Transitions

Since its conceptualization in the 1990s by Hooghe and Marks, multi-level governance (MLG) has emerged as a key framework for understanding how authority and policymaking activities are distributed across territorial levels [76]. MLG's dual focus on vertical (hierarchical) and horizontal (cross-sectoral) interactions highlights the complex interplay among governments, non-state actors, and civil society in decision-making processes. This framework has proven value in addressing global challenges like climate change and energy governance, where traditional top-down models often fail to account for ecological, cultural, and administrative diversity [72,75,77].

MLG's flexibility makes it particularly suited for the energy sector, where governance spans local, national, and global scales. By fostering collaboration across tiers, it ensures policies are context-sensitive, inclusive, and responsive to local socio-economic realities [71,73]. However, practical implementation faces significant challenges. For instance, decentralization without adequate financial and institutional support may weaken local governance capacities, [78]. Additionally, contradictions in low-carbon policies can result in blame-shifting and diluted accountability when clear oversight mechanisms are absent [79].

In contexts like Nigeria, achieving a balance between local autonomy and cohesive national energy policies remains a critical issue. Hermanson, (2018) [80] emphasizes the importance of leveraging local knowledge and best practices while aligning them with national objectives. Similarly, integrating energy policies with other sectors—such as housing and transportation—is essential for holistic governance and sustainable development. Despite these challenges, MLG provides a robust framework for interpreting the dynamic interplay of stakeholders and advancing inclusive, adaptable energy transitions [81,82].

Variations in Multi-Level Governance (MLG)

Hooghe & Marks, (2003) distinguish between two distinct models of CRE to underscore its structural variations. Type I governance is consistent with federalist

principles, characterized by a limited number of stable, general-purpose jurisdictions that balance centralized and decentralized powers through hierarchical interactions [80,83,84]. In contrast, Type II governance is characterized by numerous, overlapping, and task-specific jurisdictions prioritizing flexibility and responsiveness to dynamic, evolving demands [80,85]. While both models facilitate multi-tiered coordination, they diverge in terms of structural stability and functional scope, reflecting the diversity of governance approaches required to meet contemporary challenges [77,86]. Accordingly, it is important to note that the approach adopted in this study aligns more closely with Type II governance, given its focus on flexibility, task specificity, and responsiveness to dynamic governance needs.

4.2.3 Integrating CRE-MLG framework in sustainable transitions

This paper synthesizes multi-level governance (MLG) theory and community renewable energy (CRE) practices to explore the dynamic relationships among actors in community energy development. These relationships span federal, regional, local, and community levels, reflecting the multi-faceted and evolving nature of energy governance. The design of MLG frameworks for CRE adoption in Nigeria emphasizes the importance of inclusive participation, ensuring that all relevant stakeholders contribute to energy system transformation and effective policy responses.

Central to this integration is the dual role of the state—not only as a governance-taker but also as a governance-shaper [75]. Navigating energy transitions in Nigeria presents unique governance challenges, as physical infrastructure evolves alongside socio-economic institutions, societal norms, and key actors [87]. Achieving global energy transitions requires concerted action across governance scales, from municipal authorities to national governments [71]. Bauwens, (2017) [57] further underscores the disruptive nature of transitioning from fossil fuels to renewable, distributed energy systems, predicting that such shifts demand resilient and adaptive energy infrastructures capable of rapid deployment while maintaining essential services.

CREs, as citizen-driven initiatives, provide localized, participatory solutions that support the transition to sustainable energy technologies. These initiatives emphasize community collaboration to reduce dependency on centralized energy generation, where users are often disconnected from energy production methods [57]. The integration of MLG and CRE into a unified framework could help Nigeria to meet its

Nationally Determined Contributions (NDCs) while decentralizing energy ownership and management. This approach fosters inclusivity, empowering communities to actively participate in the transition to low-carbon energy systems, thereby aligning with both national climate objectives and sustainable development goals.

The transition to a low-carbon future necessitates multi-level coordination across policies, cultures, societies, markets, and industries [88]. MLG can enable Nigeria to redirect resources from hydrocarbon-powered generators toward sustainable energy alternatives, effectively aligning energy governance strategies with national and local objectives. This alignment requires combining legal mandates with voluntary mechanisms to drive collective action [77]. This alignment requires combining legal mandates with voluntary mechanisms to drive collective action.

4.2.4 The Nigerian Energy Landscape: A Critical Examination

Nigeria's energy sector is a paradox of scarcity amidst abundance. Despite its vast natural resources and status as one of Africa's largest oil producers [89–94], the country has consistently failed to provide reliable electricity for its growing population, which exceeds 200 million [95,96]. Current electricity generation remains capped at an intermittent supply of 5,000MW—grossly inadequate for national needs [97–99]. These chronic shortages underscore systemic inefficiencies that persist despite decades of reform efforts and substantial resource allocation [98,100,101].

Successive governments have invested heavily in energy sector reforms, with expenditures reportedly ranging from 20 trillion naira (\$11 billion) to over 6.8 trillion naira since 1999 [97,102]. However, inconsistent reporting and financial opacity make it difficult to ascertain the true scale and impact of these investments. Meanwhile, Nigerians continue to rely heavily on hydrocarbon-powered generators due to the inadequacy of public infrastructure [90,93]. In 2014 alone, approximately N796.4 billion (\$1.59 billion) was spent on generator fuel, cementing generators as an indispensable feature of daily life across both urban and rural communities [42,103].

This reliance on generators imposes severe economic, environmental, and health burdens. Households and businesses spend an estimated \$12 billion annually on generator fuel, with an additional \$13 billion allocated to generator purchases [41,42,44–46,103,104]. These expenditures reflect profound economic inefficiencies driven by energy insecurity. Furthermore, the widespread use of generators

exacerbates public health crises, with carbon monoxide poisoning and air pollution causing thousands of deaths annually [43]. These unsustainable patterns underscore deep structural failures in Nigeria's energy system, highlighting the urgent need for transformative reforms and sustainable energy solutions.

For millions of Nigerians, particularly in rural and underserved areas, access to reliable electricity remains a persistent challenge. Chronic load shedding and frequent outages have become defining features of Nigeria's energy crisis [91]. Decades of policy reforms and government assurances have failed to deliver meaningful solutions, leaving many citizens dependent on expensive and environmentally harmful alternative energy sources. This situation underscores systemic governance failures that continue to perpetuate energy poverty, particularly among vulnerable populations [105].

A fragmented and incoherent policy landscape further exacerbates Nigeria's energy challenges. Overlapping and conflicting policies obstruct the development and execution of comprehensive energy strategies [106]. This lack of coordination has resulted in inefficient, piecemeal interventions and missed opportunities for synergies between stakeholders and governance levels. The absence of a cohesive framework has been especially detrimental in rural areas, where energy poverty is most acute, and infrastructure remains largely non-existent.

Nigeria's centralized approach to energy policy has further entrenched these issues. Centralized governance structures frequently fail to address local energy needs, excluding critical stakeholders—such as local governments and community representatives—from decision-making processes [36]. This exclusion hinders the deployment of decentralization of energy systems, which is indispensable for expanding energy access in underserved regions [105].

A locally grounded solution in Nigeria's energy governance framework is essential to address these systemic challenges. The Community Renewable Energy–Multi-Level Governance (CRE-MLG) framework could provide a pragmatic and inclusive solution by decentralizing energy decision-making and integrating local stakeholders into governance structures [107].

4.3 Research Methodology

This paper adopts a qualitative inductive approach [108], to explore the complexities of CRE adoption and governance in Nigeria. Recognizing that knowledge is constructed and multifaceted in line critical realism (See Section 4.3) this methodology facilitates an in-depth understanding of the nuanced challenges, drivers, and barriers within the Nigerian energy system. Data collection involved semi-structured interviews with fifteen (15) experienced state and non-state actors, key players within the Nigerian energy supply sector, who provided insights into the dynamic interactions shaping CRE governance. Thematic analysis, guided by Braun and Clarke's six-step framework [109–111] was employed to analyze the data. Coding began with manual methods, followed by NVivo 12 software for enhanced data management and analysis.

The choice to adopt a qualitative approach stemmed from the inherent limitations of quantitative methods in capturing the socio-behavioral and contextual realities of CRE adoption. Quantitative analysis can fail to reflect the diverse social dynamics and localized nuances that shape energy transitions, particularly in regions with complex socio-economic environments [112]. Studies have demonstrated that non-economic social influences, such as cultural and behavioral factors, can play a pivotal role in renewable energy (RE) adoption [113]. Additionally, research on CRE initiatives has revealed the heterogeneous nature of human behavior, emphasizing the insufficiency of purely quantitative methods in addressing socio-demographic, psychological, and financial variables influencing CRE investments [114].

The research methodology was designed to provide a robust empirical foundation for exploring the adoption and implementation of community renewable energy (CRE) within the multi-level governance (MLG) framework in Nigeria. This approach integrates three interconnected components. First, the CRE-MLG framework (see Section 2.3, Figure 2-3) served as the conceptual anchor, shaping the overall research design and guiding the literature review. This framework was instrumental in capturing the complexities and nuances of CRE adoption in a sub-Saharan African context, addressing both theoretical and practical dimensions. Second, semi-structured interviews with key industry stakeholders were employed to gather in-depth insights into the dynamics of CRE implementation, offering rich qualitative data rooted in lived experiences and professional expertise. Third, reflexive thematic analysis [109] was used to generate themes from codes which provided a systematic approach to

identifying and synthesizing broader patterns and themes from the interview data, enabling a structured presentation of findings. Figure 4-1 provides a comprehensive summary of the methodology designed for this research. This method provides insights into stakeholder perspectives and dynamic interactions, offering a nuanced view of governance within the energy sector.

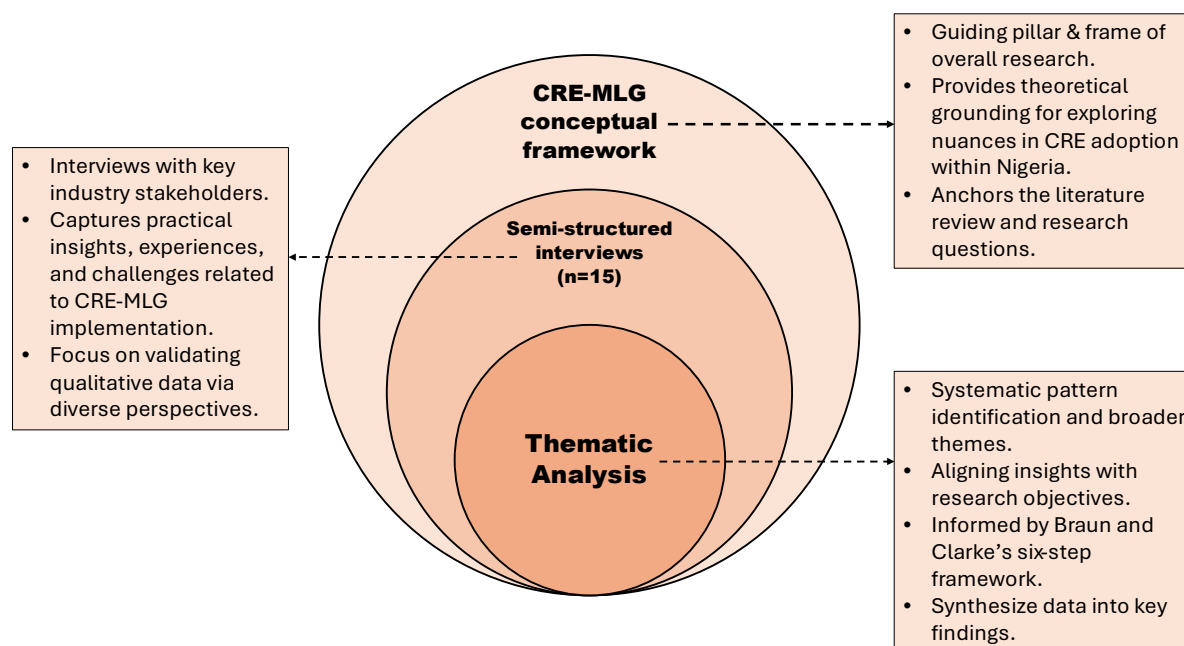


Figure 4-1. Conceptual Overview of the Methodology.

4.3.1 Data Collection

Semi-structured interviews were conducted with 15 experienced industry stakeholders (see Table 4-1). This method provided flexibility in discussions while ensuring that key themes, such as the potential adoption of community renewable energy (CRE) and multi-level governance (MLG) within Nigeria's energy sector, were systematically addressed. This approach encouraged participants to share detailed insights, generating rich qualitative data and offering nuanced perspectives on the complex dynamics of CRE implementation.

To preserve anonymity during analysis, participants were identified as Interview Participants (IPs). These anonymized individuals, representing state and non-state actors, were selected for their extensive knowledge of the energy supply system. This diverse pool (see Table 4-1) included representatives from federal, state, and local governments, private renewable energy vendors, academia, and distribution

companies, ensuring a broad and balanced range of perspectives. However, we did not separately interview energy-focused NGOs in this strand because the sampling frame prioritized statutory and operational implementers (approvals, delivery, grid interfaces). NGO perspectives were instead drawn on in the literature and are reflected via citizen-facing themes; future work will purposively include national energy NGOs to broaden this lens.

Table 4-1. Overview of Experienced (Industry) Stakeholders interviewed.

ACTOR RANK	INDUSTRY	GOVERNANCE LEVEL	CODE
Director, Procurement	Rural Electrification Agency	FG-SA	IP1
Representative of Federal Parliament	Legislator, National Assembly	FG-SA	IP7
Director, Renewable & Rural Power Access	Federal Ministry of Power	FG-SA	IP10
Director General	Plateau State Energy Corporation	SG-SA	IP5
Director, Energy Access	Ministry of Water Resources and Energy	SG-SA	IP8
Executive Chairman	Local Government I	LG-SA	IP11
Executive Chairman	Local Government II	LG-SA	IP12
Executive Chairman	Local Government III	LG-SA	IP13
Executive Chairman	Local Government IV	LG-SA	IP14
Professor, Solar Thermal	Academia	PS-NSA	IP2
Director, Biz Development	Distribution Company (DISCO)	PS-NSA	IP3
Director, Engineering	Distribution Company (DISCO)	PS-NSA	IP4
Managing Director/CEO	Private RET Vendor I	PS-NSA	IP6
Managing Director/CEO	Private RET Vendor II	PS-NSA	IP9
Chief Engineer	Generating Company (GENCO)	PS-NSA	IP15

**FG-SA=Federal Government-State Actor; SG=State Government-State Actor; LG=Local Government-State Actor; PS-NSA=Private Sector Non-State Actor*

All participants hold senior-level positions with at least 25 years of professional experience. Interviews, which lasted between 35 minutes and one hour, were conducted primarily in person at participants' workplaces, except for one interview conducted via telephone due to logistical constraints.

4.3.2 Data Analysis

Upon completing the interviews with state and non-state actors (Table 4-1), all audio recordings were transcribed for detailed analysis. The transcriptions underwent a systematic inductive coding process [110], where codes emerged directly from the data [108], capturing unanticipated themes and novel insights. Additionally, a priori

codes derived from the CRE-MLG literature review ensured alignment with the study's research questions. This dual approach validated theoretical concepts while uncovering context-specific dynamics unique to Nigeria's energy sector.

To preserve the richness of the data, participant narratives were presented in their original form wherever possible, capturing sentiments and contextual nuances. This approach ensured that the essence of the interviews was retained, avoiding thematic fragmentation. Additionally, *memoing* during interviews added depth to the analysis by capturing implicit attitudes and emotional undertones, offering a deeper understanding of stakeholders' experiences and priorities.

4.4 Results

This section presents the thematic analysis results, focusing on four key themes (Table 4-2), that address the two research questions outlined in Section 4.1. These findings examine how decentralized governance can foster renewable energy transitions by empowering local governments to facilitate CRE uptake in Nigeria.

Table 4-2. Key Themes in Community Renewable Energy (CRE) Adoption.

S/N	Themes	Description
1.	Local Governments and CRE adoption	This theme explores the role of local governments in facilitating CRE, drawing from stakeholder perspectives on governance, capacity, and local implementation strategies.
2.	Collaboration between tiers of Government	This theme examines the interplay between different tiers of government, highlighting synergistic collaboration as a critical factor for effective CRE implementation in Nigeria.
3.	Citizen Engagement in Renewable Energy Transitions	This theme explores the transformative impact of citizen participation, focusing on community-driven solutions and the critical role of inclusivity in RE adoption.
4.	Enablers and Barriers to RE transitions	This theme delves into the contextual enablers and barriers to governance implementation and CRE adoption.

The results are organized thematically, with sub-themes highlighting patterns and relationships within the data. Where relevant, quantitative insights and participant responses are included to strengthen the empirical foundation of the analysis.

4.4.1 Local Governments and CRE adoption

This theme elucidates the pivotal role of local government as a key tier in Nigeria's multi-level governance framework for driving the adoption and implementation of CRE. Analysis of participant responses highlights the multifaceted ways local governments can operationalize CRE by aligning them with local contexts and community needs, as summarized in Figure 4-2.

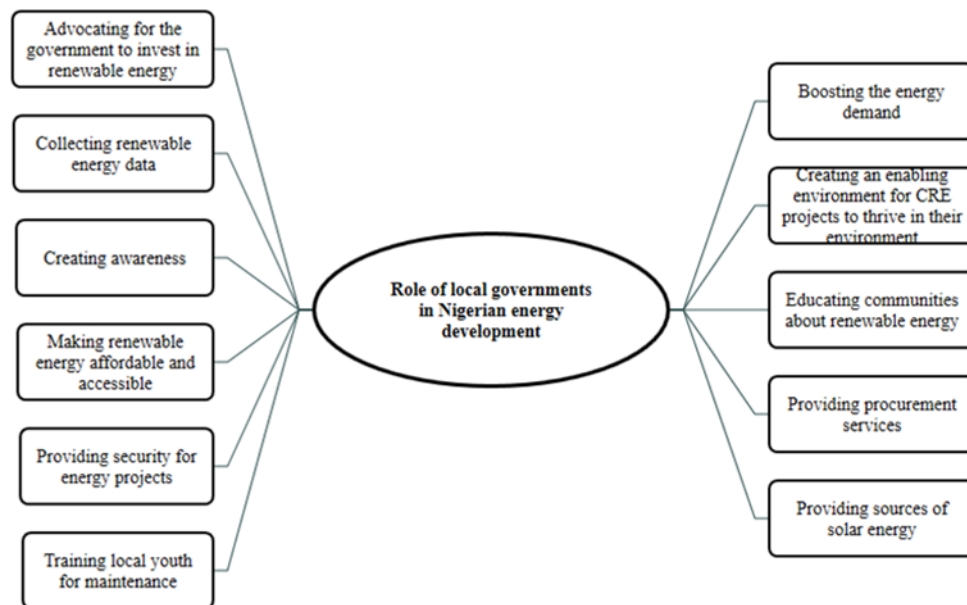


Figure 4-2. Proposed roles of Local Government in CRE adoption.

Looking at the image drawn from our Nvivo analysis in Figure 4-2, there are some nuances in the findings. Among the roles identified, enhancing community awareness emerged as a cornerstone, with majority of the participants advocating for local governments to leverage localized communication strategies to increase understanding and support for CRE as a sustainable alternative to power instead of self-reliance on hydrocarbons [41]. In addition, that knowledge can then be communicated to higher tiers of Government. This was noted by Federal and Local Government participants:

A federal government participant noted:

“The local government is closest to the people. So, they know the terrain more than us. We have to make them involved in our policy formulation by opening roles and responsibilities they can partake in while we monitor.” - IP10

Mirrored by local government executive, for example:

“Through awareness, local governments can also be the ones that would give the federal government the best information. We are the ones on the ground and know these localities very well.” - IP04

The quotes in terms of being ‘on the ground’ and ‘terrain’ was also typical of participants referring to a physical sense of place and awareness that was more in their reach than higher tiers of government.

Data collection was also consistently emphasized as a critical role for local governments in supporting adoption of renewable energy. Six participants pointed out that reliable, context-sensitive and up-to-date data, systematically organized by local governments, could provide essential insights for the design of CRE policies. Unlike data sourced from contractors, who may manipulate figures for personal or political gain, data gathered directly by local governments—whose communities are the primary beneficiaries—was seen as more trustworthy. A federal government participant underscored this point, stressing the importance of unbiased, organic energy data:

“You can politicize any form of data for political reasons, but you should never politicize data that concerns energy. Once energy data is tampered with, you won’t understand anything you plan from that point onwards.” - IP01

Moreover, two participants saw local governments not only as agents for reliable data collection, but advocates for boosting demand for renewable energy technologies (RETs) by creating an enabling environment. This includes offering practical support such as land provision and local security for projects etc., as one private sector participant observed:

“The local government has the capacity to create an enabling environment... They can provide private security to guard projects, provide free land for installations, and free access to basic things investors will need etc... These are the little things they can do to create an enabling environment for CRE to thrive in their domains.” - IP09

In addition to the local government’s capacity to create an enabling environment, the inefficiency of centralizing technical services were highlighted, advocating for local governments to train local youth for maintenance was raised, as reflected in the rhetorical concern by a mid-level government executive about the inefficiency of centralizing such services,

“Do you expect engineers from the capital (Abuja) to come and do maintenance or service it when broken?” - IP12.

Participants pointed to the critical need for decentralizing energy institutions and involving local governments in energy governance to make energy affordable and accessible with LGs looked to ‘unblock’ the system. For example, according to four participants, many RET investors find the process of acquiring land very herculean and expensive. As a result, local governments, with their established relationships with community stakeholders, could act as a conduit or negotiate on land accessibility for community benefit, potentially making land affordable or even free, thereby lowering investment costs and improving accessibility and affordability to renewable energy for underserved communities.

So far these insights collectively help underscore the critical role of local governments in addressing the logistical and socio-economic challenges associated with CRE adoption. However, not all participants agreed on LGs capacity to handle such responsibilities. A dissenting participant highlighted the limitations of local governments, citing revenue constraints and competing priorities. According to them,

“Personally, for me, considering the economic situation, the LG revenue, and competing needs like basic health and education... The LG should concentrate on their minor priorities because energy business is too complicated for it.” - IP14

This insight presents a useful word of caution, noting the range of skills LGs would be called upon to exercise. Despite this divergence, the overwhelming consensus in this theme among participants reaffirms that local governments, with proper capacity building and support, can play transformative roles in decentralizing energy governance and advancing CRE uptake. They can foster community awareness, bridge policy gaps, and ensure the alignment of energy projects with local socio-economic realities.

4.4.2 Collaboration Between Tiers of Government

Collaboration among different tiers of government emerged as a central theme in addressing Nigeria’s energy transition challenges. The overall view of this theme highlights a clear consensus among participants i.e., achieving sustainable energy goals, particularly through CRE, requires a synergistic approach between federal, state, and local governments. This intergovernmental cooperation resonates with the broader discourse in Section 4.3, where Coen et al., [115] emphasis the necessity of

collaborative governance structures in managing complex and multifaceted policy challenges.

Pulling all these strands together, the picture painted by majority of the participants repeatedly is of the local government being pivotal in bridging the gap between national policies and local implementation (See word cloud; Appendix B). This role becomes even more critical in achieving Nigeria's Nationally Determined Contributions (NDCs) and Sustainable Development Goal 7 (SDG7). One participant succinctly articulated this sentiment, stating,

"The local government can help the federal government in achieving its national determined contribution goals in the energy sector if we are involved and work together."— IP06.

A way forward in bringing better links was suggested in relation to policymaking. The lack of inclusion of local governments in energy policymaking was cited as a significant impediment to achieving these national goals and conversely engaging them in the process a means of better policymaking. Many participants argued that collaborating with local governments operationally and strategically is essential for meaningful energy transitions. A federal-level executive summarized the need for collaboration:

"We cannot be doing everything from Abuja. We have to shift downwards to the lower communities of the country. We need to decentralize this energy access and allow the people to participate; maybe it would reduce the corruption in the industry."—IP12.

This perspective was echoed by another participant,

"You could have the top-level approach having the federal strategic thinking, but there should be some level of input coming from those at state and local levels."— IP03.

Proposals on integration extended beyond policymaking. When probed further, ideas around establishing decentralized energy offices across all local governments came to light. These ideas draw parallels with the existing structures in sectors like education and health, where agencies such as the Universal Basic Education Commission (UBEC) [116–118] and Primary Health Care Development Agency (PHCDA) [119,120] have offices in all local governments, enabling efficient policy execution. However, the energy sector lacks a similar decentralized collaborative framework, which participants identified as a major gap. The proposal for a new role, which we have called Renewable Energy Desk Officers (REDOs), emerged as a recurring theme, with

approximately half of the participants advocating for such officers to serve as focal points for coordinating and supervising energy policies at the local level (See Appendix B). Participants suggested that these officers could bridge the gap between federal energy directives and community-level implementation, enhancing accountability and alignment with local needs. Notable quotes supporting this proposal include:

"There should be an amalgamation of all these energy offices integrated into one desk or office at local government levels."– IP-03.

Another perspective to drive the point further, *"LGs should have the same thing, the way they have education or health agencies domiciled in all LGs. Energy offices should have the same in LGs. For instance, the REA should be decentralized, rather than being central, or a liaison officer at state (mid-govt) level and then officers in every LG."*– IP14.

Participants also called for legislative amendments to expand the scope of agencies like the Rural Electrification Agency (REA) to expand their offices to local government offices to address the specific energy needs of communities. As one respondent noted:

"There are many energy agencies domiciled in Abuja. All they need to do is harmonize an office and decentralize them to all the LGs nationwide. Especially, REA. We need to amend the Act that establishes it by expanding its scope so all the communities in remote areas feel its impact."–IP07.

The extension of this theme into ideas such as local officers with specific titles, could also address some of the capacity concerns raised in section 4.1.

4.4.3 Citizens Engagement in Renewable Energy Transitions

This theme moves from engagement between tiers of government to the profound significance of inclusive and active citizen participation in decision-making processes to foster successful renewable energy transitions. The results indicate that embedding stakeholder engagement and integrating local community perspectives are indispensable for ensuring the sustainability and relevance of CRE. By accommodating diverse interests, citizen engagement not only enhances social acceptance but also bolsters the legitimacy of policy solutions, as argued by [121].

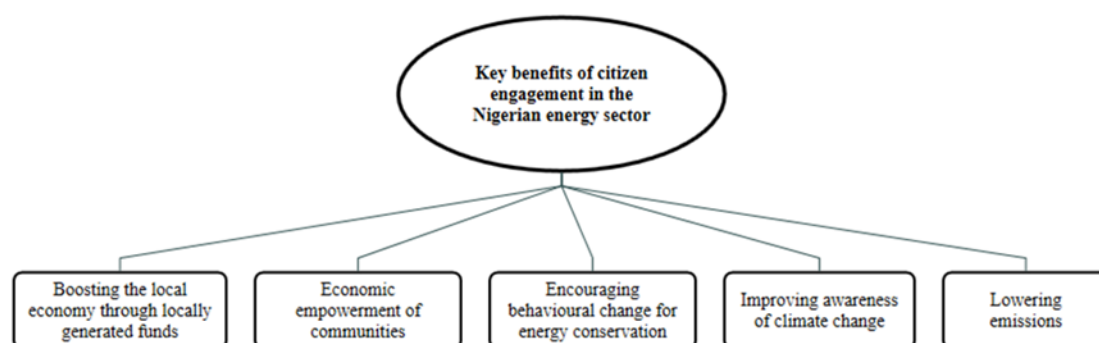


Figure 4-3. Analysis of key benefits of citizens engagement in Nigeria’s RE sector.

Figure illustrates the key benefits of citizen engagement in Nigeria’s renewable energy sector from participants’ commentaries. These include boosting the local economy through locally generated funds, empowering communities economically, promoting energy-efficient behavioral changes, raising awareness of climate change, and lowering emissions.

Improving climate awareness was one of the factors identified in fostering citizen engagement in renewable energy transitions. Participants felt that a heightened understanding of climate issues enables individuals to make informed decisions and actively participate in sustainable energy initiatives, contributing to solutions that address both local and global environmental challenges. Nine of the participants actually indicated that encouraging behavioral change is pivotal to renewable energy transitions, noting such as its role in fostering active citizen engagement to amplify public awareness and acceptance, cultivating a sense of shared responsibility or aligning individual actions with the broader socio-political objectives of sustainable energy governance.

A more complex point was noted in terms of behavioral change, that many Nigerians are accustomed to paying little for energy. It was felt this often resulted in inefficient consumption practice. A participant articulated this perspective in the following words:

“Awareness of climate change and energy efficiency. This encourages behavioral change for energy conservation. For instance, most people in Nigeria feel that energy is almost free, so they hardly switch to power sources to conserve energy.” – IP08

These points reinforce that citizen engagement in CRE is inherently multifaceted, encompassing social, financial, and legislative dimensions. Transitioning to renewable energy is not merely a technological undertaking but also a societal endeavor requiring

active and deliberate participation from communities [122]. While awareness was acknowledged as a foundational component for fostering engagement, some participants expressed skepticism about its ability to drive meaningful adoption on its own. Instead, they argued that awareness must be complemented by enabling mechanisms—such as incentives, subsidies, and affordability measures—to encourage meaningful participation and engagement. Affordability was frequently highlighted as a critical factor influencing citizen willingness to engage in renewable energy initiatives. One participant, for instance, suggested that policy reforms targeting the affordability of Renewable Energy Technologies (RETs) would significantly enhance citizen participation:

“Open the border gates to flood the country with quality and reliable RETs, especially solar companies in Nigeria, so that the price would crash, and many people can afford it. This can be done by suspending taxes and giving subsidies to these vendors.” – IP12.

This perspective highlights how affordability and policy mechanisms are not standalone considerations but essential enablers of citizen engagement in CRE adoption. By addressing economic barriers alongside awareness campaigns, policies can create an environment where engagement translates into meaningful participation.

Building on this idea, affordability emerged as a recurrent factor in discussions on citizen engagement. A participant from a Distribution Company observed the surprising willingness of rural communities to pay for reliable electricity, emphasizing that affordability and reliability are closely intertwined:

“One of the things I found amusing in many of these far-end communities we regard as villages is that, with the penetration of social media, everybody wants light to charge phones, watch local TV, and premier league matches on cable TV. These people are not poor—they’re just not flashy. Their willingness to pay for electricity depends on its reliability and availability.” – IP15.

These findings suggest that awareness, affordability, and reliability could be interdependent factors that can significantly enhance citizen engagement in RE transitions. While financial considerations are closely related to citizen willingness and ability to engage, they should not overshadow the broader thematic focus on awareness and participation. These elements serve as critical enablers for adoption, which will be explored in the subsequent theme.

4.4.4 Enablers and Barriers to Renewable Energy Transition and CRE uptake in Nigeria

The exploration of challenges and opportunities to renewable energy transition and CRE uptake in Nigeria revealed a dynamic interplay of factors driving or hindering progress. Although there is inevitable overlap with the above themes, the findings are presented here to highlight a) enablers and b) barriers, to help navigate a route map to implementation. Often enablers and barriers were two sides of the same coin.

Enablers of Renewable Energy Transition and CRE uptake

This theme identified three key enablers critical to facilitating the adoption of renewable energy and CRE in Nigeria. These include funding, supportive policies, and knowledge transfer. Factors which collectively address systemic barriers, creating a conducive environment for CRE uptake while fostering broader citizen engagement.

Funding as a Catalyst

Funding emerged as the most prominently discussed enabler, with participants unanimously emphasizing its foundational role in CRE adoption. Adequate funding was seen as essential for increasing citizen participation, alleviating financial burdens, and attracting private sector investment. Participants identified various forms of funding—such as grants, subsidies, incentives, and waivers—as critical tools to lower the financial entry barriers for both communities and investors. As referenced in the previous theme, while financial considerations are closely linked to citizen engagement, they function here as enabling mechanisms to facilitate CRE uptake in transitions.

One participant articulated the indispensable role of funding in advancing renewable energy adoption,

"Funding is the lifeline of any business, and energy supply is a big business and expensive too. So, without a doubt, funding is key" -IP11.

Another participant stressed the importance of accountability mechanisms to ensure effective use of funds:

"Clear accountability mechanisms must be established to track how funds are utilized for CRE development" -IP08.

Additionally, participants expressed a preference for grants over loans, viewing loans as burdensome and less accessible for communities. Incentivizing CRE uptake

through targeted funding strategies was also highlighted as a practical approach to stimulate participation and investment. This indicates that funding must be designed not only to bridge financial gaps but also to align with community needs and investor expectations.

Supportive Policies

Supportive policies were identified as a critical enabler for advancing the adoption of CRE in Nigeria. Participants emphasized the importance of long-term, consistent policy frameworks designed to incentivize and sustain community-driven renewable energy initiatives. These policies were seen as vital for ensuring the alignment of governance structures with the socio-economic realities of communities and the financial mechanisms required to drive CRE adoption.

Three more participants highlighted the need for policies that prioritize community participation in renewable energy projects:

“Policy should not just support renewable energy but actively incentivize community-driven approaches.” – IP07.

The interdependence between supportive policies and funding was underscored, with several participants noting that even well-designed community energy projects cannot succeed without the backing of stability:

“Without consistent funding and supportive policies, even the best community energy projects cannot take off.” – IP02.

This theme highlights the necessity of policy frameworks that are proactive, stable, and tailored to the unique challenges of CRE adoption. Participants advocated for policies that facilitate access to funding, streamline regulatory processes, and provide incentives for both communities and investors to engage in sustainable energy transitions. Such policies were seen as pivotal in creating an enabling environment that encourages long-term investment and community ownership of energy solutions.

Knowledge Transfer and Capacity Building

The transfer of knowledge and technical expertise emerged as a crucial enabler for the adoption and sustainability of CRE. Participants highlighted that localized knowledge dissemination and capacity-building initiatives are essential to equip communities with the technical skills required to operate and maintain CRE

technologies. This was seen as a critical factor not only for ensuring system longevity but also for fostering local ownership and reducing dependence on external technical expertise.

Underscoring the importance of knowledge capacity for the effective and sustainable adoption of CRE systems, a state government CEO asserts:

“Knowledge capacity is important... people must understand the technology, maintain it locally, and pay for its services.” – IP13.

Participants advocated for structured training programs that target local communities and stakeholders involved in CRE. These programs were seen as essential for building the technical expertise necessary to manage and sustain CRE systems independently. Additionally, localized knowledge transfer was linked to the broader social acceptance of renewable energy technologies, as it fosters trust, ownership, and a sense of empowerment among community members.

Summarily, funding, supportive policies, and knowledge transfer form the cornerstone of enabling renewable energy transition and CRE adoption in Nigeria. Adequate funding—particularly in the form of grants rather than loans—coupled with transparent allocation mechanisms, can catalyze investments and grassroots adoption. Supportive policies must be long-term, consistent, and actively incentivize community-driven projects, while localized knowledge transfer ensures the technical sustainability and social acceptance of CRE initiatives. Together, these enablers present a cohesive roadmap for overcoming inertia in Nigeria’s energy transition.

Barriers to Renewable Energy Transition and CRE uptake

Participants identified several current barriers impeding renewable energy adoption in Nigeria. These barriers span financial, technical, regulatory, and infrastructural challenges, reflecting the complexity of implementing CRE in the Nigerian context.

Policy and Regulatory Challenges

With a key enabler being supportive policies, one of the most frequently cited barriers to renewable energy adoption in Nigeria was the current policy landscape and the absence of an effective policy, legal, and institutional framework. Participants highlighted regulatory inconsistencies and the lack of clear mandates for government involvement at all levels as significant obstacles to the implementation of CRE. These

issues were seen as undermining the development of a cohesive and supportive environment for RE transitions.

A participant underscored the need for a robust policy framework:

“There should be a specific policy framework that mandates the involvement of all governance tiers in CRE implementation.” – IP03.

However, some participants challenged the notion that policy creation alone could address these barriers. Instead, they pointed to gaps in policy implementation and the lack of political will as more pressing issues. As one participant observed:

“The problem is not policy but the lack of political support and funding for take-off.” – IP05.

This divergence of views highlights that while the creation of a comprehensive policy framework is essential, it must be accompanied by structural reforms and a strong political commitment to ensure effective implementation.

The findings reveal that addressing policy, regulatory, and institutional challenges requires the development of consistent and inclusive frameworks, alongside a sustained commitment to bridging the gap between policy design and practical implementation. Participants highlighted the interconnected nature of these challenges, where inconsistent political and institutional support exacerbates the inefficiencies caused by regulatory gaps.

Inconsistent Political and Institutional Support

The lack of sustained political commitment emerged as a significant barrier to renewable energy transitions and CRE adoption in Nigeria. Participants emphasized that token efforts and symbolic gestures, often lacking follow-through, undermine the success and credibility of CRE initiatives. One non-state actor described this vividly:

“I have seen firsthand where there was limited government support for critical renewable energy initiatives even after a much-celebrated launch on TV... just lip service.” – IP07.

This inconsistency diminishes trust among stakeholders, including private investors, NGOs, and local communities. Participants noted that renewable energy projects require long-term institutional backing to navigate policy execution, stakeholder coordination, and project financing. Without sustained political will, even well-resourced initiatives risk abandonment or ineffectiveness.

Funding Challenges

The lack of adequate and targeted financing mechanisms emerged as a critical barrier to renewable energy transition and CRE adoption in Nigeria. Participants consistently pointed to the high cost of renewable energy technologies (RETs) as a major deterrent to community uptake, highlighting the financial disparities that restrict access to clean energy solutions.

A senior federal government official emphasized this challenge:

“High cost of energy...most people that can afford renewable energies at their houses are only the financially buoyant people.” – IP10.

Participants’ discussions further distinguished between three key funding challenges, each tied to specific contexts:

1. Funding for Renewable Energy Technologies (RETs)

High upfront costs of RETs, combined with limited access to financing options such as subsidies or grants, were identified as significant barriers for both households and communities. Participants noted that most communities lack the financial resources to invest in RETs without external support, emphasizing the need for targeted funding mechanisms to lower entry barriers and foster grassroots adoption. Enabling quality control for good value for money was also noted. For instance, one participant lamented,

“What is found in the market are sub-standard versions, and when they break down, it discourages citizens from actively participating in this transition” -IP07.

This also aligns with calls for sustainable and localized systems for maintenance and repair – see below.

2. Funding for Governance Structures

Participants highlighted that inadequate funding for the development and operationalization of governance frameworks, such as Renewable Energy Desk Officers (REDOs), undermines the ability to create inclusive and sustainable energy systems. Without financial resources, these governance structures cannot effectively coordinate or implement CRE projects, leaving critical gaps in policy execution and project oversight.

3. Funding for Local Government (LG) Capacity Building

Participants stressed the importance of equipping local governments with the financial resources necessary to build capacity for CRE implementation. This includes training programs, technical expertise, and infrastructural support. A participant observed that without dedicated funding for capacity building, local governments would struggle to assume their roles as key enablers of CRE adoption.

These findings underscore the diversity and complexity of funding challenges in Nigeria's renewable energy transition. Addressing these issues requires not only increasing the availability of funding but also designing mechanisms that cater to the unique needs of various stakeholders, from individual households to governance institutions.

Inadequate Technology and Technical Expertise

As noted above, a lack of technical know-how and maintenance capacity was also underscored as a significant barrier. Participants noted the dependency on imported equipment and the absence of local expertise for repairs and maintenance.

As one state actor summarized,

"The resources like solar and wind are in abundance, but the technology to convert these sources to energy is absent. Most of the equipment is imported. If we have the money to purchase, how about maintaining it?"

This is a common complaint in relation to new technologies and the lack of local and embedded supply and maintenance chains. This could be a focus of attention for LGs.

Knowledge Gaps and Public Awareness

Limited public awareness and insufficient capacity building at the grassroots level were additional barriers extensively discussed in theme 1 (section 4.1). Participants stressed the importance of educating citizens about renewable energy technologies and fostering a sense of ownership to reduce vandalism and improve adoption.

The findings from this theme highlight the dual nature of enablers and barriers in Nigeria's renewable energy landscape. While funding, supportive policies, and knowledge transfer are critical enablers, barriers such as high costs, inadequate technology, inconsistent political support, and ineffective frameworks continue to hinder progress. These results set the stage for a deeper discussion of strategies to

overcome these barriers and fully leverage the potential of enablers in driving a sustainable energy transition in Nigeria.

4.5 Discussion

This section synthesizes the findings, critically addresses the two research questions, and discusses and broader implications for transforming renewable energy governance in Nigeria. By drawing together four key thematic areas, this section highlights how decentralization, citizen engagement, and intergovernmental collaboration can serve as transformative pathways for CRE adoption. The findings are interpreted through the lens of the CRE-MLG framework, which emphasizes multi-level coordination, inclusivity, and decentralized policy implementation as fundamental to addressing energy poverty and promoting sustainable energy systems.

The discussion is guided by the two central research questions outlined earlier, which form the foundation for this analysis:

To what extent can Nigeria's current energy governance framework be adapted to stimulate and support community renewable energy (CRE) adoption?

How can local governments (LGs) effectively connect communities with other tiers of government when implementing CRE in Nigeria?

By leveraging the CRE-MLG framework as a conceptual anchor, this discussion delves into the governance dynamics, enablers, and barriers shaping Nigeria's renewable energy transition. The goal is to move beyond descriptive findings, critically analyzing the insights, challenges, and nuances that underpin this work, and ultimately providing a roadmap for bridging the gap between policy design and practical implementation.

4.5.1 Adapting Nigeria's Current Energy Governance Framework

Nigeria's current energy governance framework is predominantly centralized and hierarchical, which limits its capacity to stimulate CRE adoption[89]. While centralization provides uniformity in policy formulation, it creates inefficiencies in implementation, particularly in addressing local socio-economic realities. This section explores how decentralization, policy reforms, and targeted economic mechanisms can address these challenges and unlock the potential of CRE adoption.

Decentralization as a Governance Strategy

The study underscores decentralization as a critical enabler for adapting Nigeria's governance framework. By shifting decision-making authority closer to communities,

decentralization offers the flexibility to tailor energy solutions to local needs. However, the findings reveal that decentralization in Nigeria faces significant implementation challenges due to the absence of institutional structures, limited financial autonomy, and resistance from centralized authorities who may perceive it as a threat to their control.

The proposal for Renewable Energy Desk Officers (REDOs) highlights how decentralization can be translated into actionable governance. Positioned at the local government level, REDOs could bridge the gap between national policies and grassroots implementation, ensuring that energy initiatives align with community needs. In contrast to the current system, which often overlooks the capacities of local governments [123,124], REDOs would institutionalize accountability and transparency in policy execution. As locally embedded technical officers, REDOs would serve as visible focal points for coordinating renewable energy programmes, collecting implementation data, and reporting performance to supervisory bodies. This structure not only reinforces upward accountability to central authorities, but also downward transparency to local communities. Similar decentralized roles in Nigeria's health and education sectors, such as Primary Health Coordinators and UBEC Desk Officers, illustrate the feasibility of this model in practice. This approach reflects an important shift in governance, emphasizing local ownership of energy initiatives while ensuring that local governments are not merely policy implementers but active participants in energy planning.

Globally, decentralization has been key to successful energy transitions in countries like Denmark and Germany [125–128], where local governments and cooperatives play pivotal roles. However, these contexts benefit from robust legal and financial frameworks that support decentralized governance, highlighting the need for Nigeria to create similar enabling conditions. Without this, decentralization risks being superficial, with local governments unable to operationalize their potential roles.

Enablers: Supportive Policies and Economic Mechanisms

The findings reveal that supportive policies are foundational to governance reforms. Participants emphasized the importance of policies that are both stable and inclusive [129,130], ensuring long-term support for community-driven renewable energy initiatives. However, many existing policies in Nigeria lack coherence, leaving gaps in implementation and accountability. This gap underscores the importance of

prioritizing a participatory approach to policy design, ensuring that the voices of local governments and communities are integrated from the outset. Economic mechanisms, such as grants, subsidies, and tax incentives [131,132], were highlighted as critical tools for reducing the financial burden of Renewable Energy Technologies (RETs). While funding mechanisms offer significant potential, their success depends on transparency and equitable distribution, which are currently lacking in Nigeria's energy governance system. This reinforces the critical role of REDOs in monitoring and disbursing funds to ensure alignment with national priorities while addressing local energy needs.

Barriers: Regulatory Inconsistencies and Political Commitment

Regulatory inconsistencies emerged as a significant barrier to adapting Nigeria's governance framework. While existing regulations provide some guidance on energy transitions, they often fail to clarify the roles of local governments, leading to inefficiencies and a lack of accountability. The study recommends a cohesive regulatory framework that clearly delineates and harmonizes the responsibilities of federal, state, and local governments in renewable energy governance. At the federal level, the focus would be on policy formulation, national target-setting, funding mechanisms, and inter-agency coordination. State governments would facilitate regional planning, contextualize federal policies, and support cross-LGA collaboration. At the local level, LGAs—through REDOs—would engage communities, coordinate projects, gather data, and feed insights upward.

This integration would be operationalized through a Multi-Tier Coordination Platform (MTCP), featuring regular stakeholder forums, shared performance dashboards, and intergovernmental implementation task forces. Such mechanisms would promote policy coherence, reduce duplication, and ensure that local energy needs inform national objectives [133]. Participants also highlighted the lack of sustained political commitment as a critical challenge. Token gestures, such as program launches without follow-through, not only undermine project sustainability but also erode trust among stakeholders. Institutionalizing mechanisms like REDOs could address this issue by creating a system of accountability and sustained engagement.

4.5.2 Empowering Local Governments to Connect Communities with Other Tiers of Governance

Local governments are uniquely positioned to act as intermediaries between communities and higher governance tiers. However, their potential remains underutilized due to systemic barriers such as inadequate resources, capacity gaps, and governance silos. This section examines how local governments can overcome these challenges through capacity-building, citizen engagement, and intergovernmental collaboration.

Building Local Capacity

The findings highlight the importance of capacity-building initiatives in empowering local governments. While local governments are closest to communities and understand their needs, their effectiveness is constrained by limited technical expertise and financial resources. Moreover, the findings reveal a deeper challenge i.e., capacity gaps are not merely a function of resource constraints but also reflect structural issues within Nigeria's governance system, where local governments are often excluded from strategic decision-making processes. REDOs, as proposed in this study, could address these gaps by providing technical training, coordinating resources, and facilitating knowledge transfer. However, capacity-building efforts must be embedded within a broader framework of institutional reform. For instance, technical training alone will not suffice if local governments lack the autonomy to make decisions or if resources remain centralized. Addressing these systemic barriers is crucial to ensuring that capacity-building initiatives translate into meaningful improvements in local governance[134,135].

Fostering Citizen Engagement as a Driver of Energy Justice

Citizen engagement is critical for ensuring the long-term sustainability of CRE initiatives [136,137]. While awareness campaigns are a necessary starting point, they are insufficient without complementary measures to build capacity and address economic barriers. Participants emphasized that affordability and accessibility must be prioritized alongside awareness to foster meaningful participation. For example, the findings highlighted that rural communities often express a willingness to engage with CRE projects, provided these initiatives offer tangible benefits, such as reliable and affordable energy. However, achieving energy justice requires more than addressing affordability; it necessitates transparent and inclusive decision-making processes that

actively involve and respect communities at every stage of project development. In contrast to top-down approaches that marginalize communities, inclusive decision-making processes build trust and a sense of ownership. By embedding citizen participation into the CRE-MLG framework, local governments can foster energy justice, ensuring that projects align with community needs and aspirations [122,138].

Intergovernmental Collaboration for Efficient Governance

The study underscores the importance of intergovernmental collaboration in overcoming governance silos and fostering synergy across tiers. While collaboration is critical, the findings reveal significant gaps in resource coordination and communication among federal, state, and local governments [37,139]. These disconnects often result in delays and inefficiencies in project implementation. REDOs could play a pivotal role in facilitating collaboration by serving as coordinators across governance tiers. However, their success depends on trust and transparency among stakeholders, which are currently undermined by inconsistent political support and misaligned priorities. Addressing these issues requires not only structural reforms but also a cultural shift toward inclusive and accountable governance.

Addressing Barriers to Local Government Effectiveness

The findings also highlight several barriers that hinder local governments from effectively connecting communities with other governance tiers. Limited financial autonomy and inadequate institutional frameworks emerged as critical challenges. While financial constraints are a recurring issue, the lack of clear mandates for local governments further exacerbates their inability to act as effective intermediaries. Participants emphasized that targeted reforms, such as decentralized decision-making and increased funding, are essential for addressing these barriers[140–142]. In contrast to centralized governance structures that marginalize local governments, a more participatory approach would empower them to bridge the gap between national policies and community needs.

4.6 Conclusion And Recommendations for Future Research

This study critically explored the transformative potential of decentralized governance frameworks, with a focus on the proposed CRE-MLG model, to address Nigeria's persistent energy poverty and catalyze the adoption of Community Renewable Energy (CRE). While significant investments have been made in the energy sector, the continued prevalence of energy poverty—particularly in rural and underserved

regions—exposes the limitations of existing governance structures. These challenges underscore the urgency of transitioning from centralized energy policies to governance systems that are inclusive, adaptive, and aligned with local realities. Through the lens of the CRE-MLG framework, this study offers a nuanced understanding of the governance, socio-political, and economic dynamics shaping Nigeria's energy transitions and provides actionable strategies to advance Sustainable Development Goal 7 (SDG7).

4.6.1 Key Findings and Implications

This study underscores the transformative potential of decentralized governance frameworks, particularly the proposed CRE-MLG model, in addressing Nigeria's persistent energy poverty. By focusing on decentralization, citizen engagement, and intergovernmental collaboration, the findings highlight actionable pathways for fostering the adoption of CRE while addressing systemic barriers within the energy governance landscape.

Central to the study's findings is the pivotal role of local governments in bridging policy formulation and grassroots implementation. Positioned closest to communities, local governments are uniquely placed to tailor energy solutions to socio-economic realities, addressing challenges of accessibility and inclusivity. However, this potential remains underutilized due to a lack of institutional frameworks, limited financial autonomy, and inadequate capacity. To overcome these challenges, the study recommends institutionalizing REDOs at the local government level. REDOs would act as coordinators, technical advisors, and liaisons, ensuring alignment between national policies and community needs. This proposal draws inspiration from international models, such as Denmark's municipal cooperatives, which have successfully demonstrated the effectiveness of decentralized energy governance.

The findings also reveal key enablers that can accelerate CRE adoption, including innovative funding mechanisms, supportive policies, and knowledge transfer. Transparent and sustainable financial models, such as grants, subsidies, and tax incentives, were identified as essential tools for improving the affordability of Renewable Energy Technologies (RETs) and catalyzing private sector investment. Equally important are long-term, inclusive policies that prioritize community-driven initiatives while addressing regulatory inconsistencies that currently hinder progress. Knowledge transfer, through localized training programs, emerged as a critical factor

for ensuring the sustainability of CRE systems. By equipping communities with technical skills and fostering a sense of ownership, knowledge transfer can strengthen trust and engagement in energy transitions.

Despite these enablers, significant barriers persist. High costs of RETs, inconsistent regulatory frameworks, and limited technical capacity emerged as key obstacles. The affordability of RETs remains a critical challenge, particularly for low-income and rural communities, necessitating targeted interventions such as reducing import tariffs, providing tax exemptions, and promoting local manufacturing. Regulatory inconsistencies, meanwhile, create inefficiencies and undermine trust among stakeholders, highlighting the need for a cohesive framework that integrates all tiers of governance. Capacity gaps at the local level further exacerbate these challenges, underscoring the urgency of capacity-building initiatives that enable local governments and communities to effectively manage CRE projects.

The study also emphasizes the importance of multi-level governance in fostering synergies across federal, state, and local tiers. International comparisons, such as Denmark's decentralized energy governance system, illustrate how distinct roles and collaborative mechanisms can promote inclusivity and accelerate CRE adoption. However, Nigeria's unique socio-political context—marked by entrenched centralization and systemic inequities—necessitates tailored approaches that address these specific challenges. A more participatory governance framework, supported by robust institutional reforms and collaborative mechanisms, is critical for unlocking Nigeria's potential for sustainable energy transitions.

Ultimately, this study highlights the critical role of governance reform in achieving Sustainable Development Goal 7 (SDG7) and advancing Nigeria's energy future. By leveraging the CRE-MLG framework, Nigeria can address systemic barriers, strengthen stakeholder trust, and create an inclusive governance ecosystem that fosters energy justice, accelerates CRE adoption, and promotes long-term sustainability.

4.6.2 Implications for Policymakers and Academia

The findings of this study have significant implications for policymakers and academia, offering insights that can shape future governance models and research agendas in the renewable energy sector. For policymakers, the study underscores the urgent

need to decentralize energy governance by empowering local governments with financial autonomy, institutional resources, and technical expertise. Local governments, with their proximity to communities, are uniquely positioned to facilitate CRE adoption and bridge the gap between national policies and grassroots implementation. Institutionalizing REDOs at the local government level presents a practical strategy for operationalizing decentralized governance. REDOs could serve as focal points for coordinating energy policy, ensuring that governance frameworks align with community needs, and fostering transparency in the disbursement of resources.

Transparent and inclusive policies are critical for driving energy transitions. Policymakers must prioritize long-term, stable frameworks that incentivize community participation while addressing economic barriers such as affordability and accessibility. Financial mechanisms, such as grants, subsidies, and tax waivers, can play a pivotal role in making RETs affordable for underserved populations. However, the study also emphasizes the importance of engaging local governments and communities in policy design to ensure that energy initiatives are both equitable and sustainable.

For academia, the study highlights the need for comparative research to explore how MLG frameworks can be adapted across diverse contexts. Investigating the interplay between energy justice, decentralized governance, and community participation—particularly in SSA—can yield valuable insights into overcoming systemic inequities and fostering inclusive energy transitions. Additionally, longitudinal studies are critical for assessing the long-term impacts of decentralized governance models, such as REDOs, on energy adoption and socio-economic development. Such research would provide a more comprehensive understanding of the sustainability and scalability of governance innovations in different settings.

Academia also has a role to play in advancing interdisciplinary approaches to energy research. Integrating economic, social, and technological dimensions into the study of renewable energy transitions can offer a holistic perspective on the challenges and opportunities associated with decentralized governance. By generating evidence-based recommendations, academic research can guide policymakers in developing adaptive governance frameworks that address the unique challenges of energy transitions in the Global South.

Taking together, this study provides a foundation for both policymakers and academia to reimagine governance frameworks that advance CRE adoption while promoting energy justice, inclusivity, and sustainability. By fostering collaboration between researchers, policymakers, and local communities, Nigeria can create a governance ecosystem that addresses energy poverty and supports a just and equitable energy future.

4.6.3 Study Limitations and Future Research Agenda

While this study provides valuable insights into decentralized governance and CRE adoption in Nigeria, it is not without limitations. The research was qualitative in nature, relying on semi-structured interviews with a sample of stakeholders. Although this approach offered rich, context-specific insights, care is needed when seeking to generalize the findings across Nigeria or other SSA countries with distinct governance and socio-economic contexts. Future research could expand on this research by testing the methodology in different contexts.

Another limitation is the study's focus on Nigeria, which necessitates caution when applying its findings to other SSA nations. Governance structures, economic conditions, and energy policies vary significantly across the region. Comparative research examining how decentralized governance frameworks operate in different national contexts would provide valuable lessons for identifying best practices and scalable models for CRE adoption.

Additionally, the study's timeframe restricted its ability to evaluate the long-term impacts of decentralized governance models, such as the institutionalization of REDOs. Longitudinal studies are needed to assess how these frameworks evolve over time, particularly in terms of their sustainability, scalability, and socio-economic impacts. Such research would provide help support a robust understanding of the conditions necessary for their success.

The findings also highlight key areas for further investigation. For example, issues around energy justice emerged. This fell outside the scope of the study but underscores the need to explore how governance frameworks can address systemic inequities in energy access. Research focusing on the intersection of energy justice and decentralized governance would yield critical insights into ensuring equitable transitions, particularly for marginalized populations. Stakeholder dynamics also

warrant further exploration, particularly in understanding how governments, the private sector, NGOs, and communities can collaborate effectively within decentralized governance systems.

In summary, this study highlights both the potential and the complexities of advancing CRE adoption through decentralized governance. While its limitations point to areas for further research, the findings provide a strong foundation for reimagining governance frameworks that are inclusive, equitable, and adaptive to the needs of energy-poor communities.

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5 GENERAL DISCUSSION

This chapter synthesizes the findings of this thesis, reiterating its overarching aim and demonstrating how each objective has been fulfilled. The discussion critically engages with the literature, situating the results within the broader context of sustainable energy governance and community renewable energy (CRE) adoption in Sub-Saharan Africa (SSA), particularly Nigeria. The chapter also emphasizes the practical implications for policy makers, investors, and researchers, with a focus on achieving Sustainable Development Goal 7. While country-specific, these insights may inform parts of Sub-Saharan Africa where institutional conditions are comparable; transferability should be established empirically.

5.1 Thesis Motivation

The primary aim of this thesis is to **construct a sustainable energy governance framework that facilitates the development of Community Renewable Energy (CRE) policies for Nigeria's energy transition, drawing inspiration from exemplar countries such as Germany and Denmark** (See 1.1.4). Fundamentally, the thesis ultimately seeks to offer a structured approach to CRE implementation in Nigeria, aligning it with global sustainability goals, climate change mitigation, and local developmental needs.

This chapter explores the significance of the research findings within the context of the literature and elaborates on their practical implications for academia, policymakers, and other key stakeholders. Anchored in Chapter 2, which provides the literature review and conceptual framework, this discussion synthesizes the mixed-method results (see rationale in Chapter 1.5) from the empirical chapters (Chapters 3 and 4). These results, both quantitative and qualitative, converge to validate the proposed CRE-MLG framework (see Chapter 2.7). Synthesis of Thesis Objectives (Table 5-1) summarizes the novelty, scientific soundness, and contributions of the study's objectives, illustrating how these elements collectively fulfil the thesis' overarching aim.

5.2 Contextualizing the Research

While CRE is gaining traction globally, existing research remains heavily skewed toward the Global North, particularly Europe and North America [1,2]. Existing studies focus on governance models, financing structures, and institutional mechanisms

within well-established policy environments [2]. However, such frameworks may not seamlessly translate to SSA due to distinct socio-economic and political conditions.

This geographical bias creates challenges. It assumes CRE models from the Global North are universally applicable, overlooking SSA's energy insecurity, fragmented governance, and financial constraints [3]. Unlike Europe, where policy stability and government incentives drive CRE, SSA communities rely on informal networks, decentralized markets, and inconsistent policy support [2]. Moreover, while Northern studies emphasize governance typologies and financing, they often neglect local socio-cultural factors, which are central to citizen participation and energy decision-making in the global south [1].

Bridging the Research Gap: The Need for Context-Sensitive Approaches

To address this, CRE research should consider a shift beyond Global North paradigms and develop region-specific models [3]. While country-specific, these insights may inform parts of Sub-Saharan Africa where institutional conditions are comparable; transferability should be established empirically. This requires:

- CRE models that build upon informal, citizen-led economies, such as those already seen in widespread generator use, by leveraging decentralized financing mechanisms like microfinance, mobile banking, and community pooling models—not government-led investments.
- Decentralized governance approaches that do not centralize state funding, but instead empower local governments to facilitate coordination, data collation, and policy support.
- Integration of indigenous knowledge systems, recognizing that applicability varies across SSA contexts.
- Stronger regional research leadership, ensuring SSA scholars shape the CRE discourse rather than remain peripheral to it.

Germany and Denmark as Exemplar Countries

Despite the Global North's research dominance, this study identifies Germany and Denmark as models—not for direct replication but for strategic adaptation. As global leaders in CRE, these countries offer proven governance structures, financial mechanisms, and institutional models that demonstrate large-scale citizen-driven renewable energy transitions (See Chapter 2, Section 4.2).

Using struggling SSA or emerging economies as primary references could reinforce existing constraints rather than provide solutions. Many developing nations still face policy instability, financial barriers, and weak institutional structures—challenges this study aims to address rather than replicate. By analyzing best practices from structured governance environments, this research identifies adaptable elements, recalibrating them for SSA's specific energy landscape (see Chapter 2, Section 4.2.3 “Insights from Germany and Denmark”). Thus, the choice of Germany and Denmark is a methodologically sound decision—ensuring this research extracts actionable lessons from the most successful global models while contextualizing them for SSA's energy transition needs.

Building on the discussion of contextualized CRE frameworks, this research acknowledges that, despite extensive public and private investments in renewable energy across SSA, progress remains limited. This stagnation underscores the necessity of shifting from conventional top-down governance to a bottom-up model, where citizen participation plays a central role in fostering sustainable energy transitions [4–6].

Nigeria, serving as the focal case study, exemplifies these systemic governance shortcomings. Traditional top-down models have historically excluded local governments and citizens from energy decision-making, leading to persistent inefficiencies. This study challenges prevailing assumptions about SSA citizens' financial incapacity to participate in sustainable energy transitions, presenting empirical evidence to the contrary [7]. The continued failures of Nigeria's fossil-fuel-based central grid—including eight national grid collapses in 2024 [8–11]—have driven citizens toward small-scale hydrocarbon-powered generators as an alternative to supplement the intermittent grid supply [12]. With approximately \$12 billion spent annually on these generators [13–17], the financial capacity exists to support decentralized renewable alternatives, provided appropriate governance structures facilitate this transition.

This thesis posits that a bottom-up approach, integrating multi-level governance and community participation, is critical for improving energy access, fostering inclusive and sustainable energy transitions, and mitigating the multidimensional energy poverty experienced by many Nigerians [18,19]. By leveraging citizen investments to

supplement the significant financial requirements of an energy-secure nation, Nigeria can address its energy challenges more effectively. Moreover, this research argues that citizen participation is not only vital for improving local energy access but also essential for advancing sustainable energy systems that contribute to global climate change mitigation efforts.

Table 5-1. Synthesis of Thesis Objectives.

OBJECTIVE	CHAPTER	GAPS IDENTIFIED	NOVELTY	SIGNIFICANCE/CONTRIBUTION
1. Analyse the development of CRE, particularly in Germany and Denmark with a view to identify key success factors in role of citizens engagement in RE transitions via a comprehensive desktop literature review.	(2) <i>Published manuscript in Energy Research & Social Science Journal -ERSS</i>	Limited CRE literature, particularly Nigeria Limited MLG literature, particularly Nigeria. Limited understanding of CRE policy adoption in Nigeria. Gaps in knowledge on citizens' capacity to finance CRE, despite evidence of significant household spending on hydrocarbon generators (~\$12 billion annually).	Presented a narrative synthesis of CRE development in Germany and Denmark ^a , contextualized for Nigeria, with potential relevance to SSA subject to empirical validation.	Academic Contributions: <ul style="list-style-type: none"> Advanced understanding of CRE development and governance in Germany and Denmark as exemplars for Nigeria. Addressed knowledge gaps through a review of CRE-MLG framework. Policy Contribution: <ul style="list-style-type: none"> Demonstrated the untapped potential for CRE financing via redirected household expenditures.
2. Develop a conceptual framework that elucidates the interconnections and interactions between MLG and CRE, fostering the	(2) <i>Published manuscript in Energy Research &</i>	Limited strategic frameworks for CRE policy adoption in Nigeria.	Integrated CRE and MLG concepts to develop the 'CRE-MLG framework,' emphasizing decentralized decision-making, community	Academic Contributions: <ul style="list-style-type: none"> Proposed a scalable CRE-MLG framework tailored for Nigeria. Introduced REDOs as an innovative mechanism to

development of CRE within the Nigerian renewable energy landscape.	<i>Social Science Journal -ERSS</i>	Absence of a cohesive governance model integrating MLG and CRE in Nigeria.	involvement, and adaptable energy governance systems. Introduced the novel concept of Renewable Energy Desk Officers (REDOs).	operationalize decentralized energy governance. Policy Contribution: <ul style="list-style-type: none"> Offered a structured approach for bridging national policies with community energy needs, fostering inclusivity and accountability.
3. Statistically test and validate the framework by identifying the determinants of CRE acceptance and adoption in Nigeria and assess the enablers and barriers for implementation by policy makers via mixed method analysis.	(3) <i>(Quantitative Paper), under review in Energy Policy Journal.</i>	Limited quantitative analysis of CRE adoption in SSA. Lack of empirical studies exploring determinants of CRE adoption in SSA	Employed a multinomial logit (MNL) model with interaction terms (awareness × income; awareness × education) and interpreted average marginal effects (AMEs) to identify significant predictors of CRE adoption—income, education, awareness, with occupation adding nuance (civil service/NGO > informal), and gender not significant after controls; results supported by predictive marginal plots and	Academic Contributions: <ul style="list-style-type: none"> Generated an empirical dataset (n=559) on CRE adoption in Northern Nigeria and validated the MNL approach for an unordered, multi-level adoption outcome. Identified core determinants using AMEs: income (large positive effects at 15–20% and >20%), education, awareness; occupation (civil service, NGO) positive; gender not significant post-controls; age 26–45 and larger households show higher commitment.

			model diagnostics (Brant test → MNL, IIA passed, VIF < 5).	<ul style="list-style-type: none"> • Provided interaction evidence: awareness is most effective at low–mid incomes and shows diminishing returns at high incomes; awareness effects vary by education level. <p>Policy Contribution:</p> <ul style="list-style-type: none"> • Translated AMEs into targetable policy levers: focus finance + awareness where marginal returns are highest (low/lower-middle income) and pivot to quality/reliability and finance terms at higher incomes. • Informed occupation-sensitive outreach (civil service/NGO channels) and education-sensitive messaging, aligning with governance delivery through REDOs.
	<p>(4)</p> <p><i>(Qualitative Paper)</i>, Submitted to ERSS Journal</p>	<p>Limited data on enablers/barriers for decentralized energy governance in SSA.</p> <p>Limited qualitative methods and analysis for nuanced insights of</p>	Findings underscore the critical importance of decentralized energy governance setting and the role of local governments in fostering awareness, securing investments, and enabling sustainable energy	<p>Academic contribution:</p> <ul style="list-style-type: none"> • This chapter contributed to the discourse on energy transitions in SSA and presented a scalable governance model that aligns with Nigeria's climate goals and Sustainable Development Goal 7 (SDG7).

		decentralized governance in SSA	<p>solutions tailored to regional needs.</p> <p>The inductive approach in this chapter identified key patterns which validated the institutionalization of the REDO concept (Chapter 2) at local government level to facilitate coordination, deepen community engagement, and bridge the gap between national policies and grassroots implementation.</p>	<p>Policy contribution:</p> <ul style="list-style-type: none"> The proposed framework provided actionable insights for policymakers and practitioners aiming to address energy poverty and foster sustainable development through inclusive, community-driven renewable energy solutions.
Provide policy recommendations regarding the development of CRE in Nigeria, with a focus on the potential roles and responsibilities of state and non-state actors,	2, 3 & 4 (Integrated and synthesized in Chapter 5)	<p>The Nigerian Electricity Act (2023) lacks practical implementation pathways for decentralization.</p> <p>Roles for citizens' participation and local</p>	<p>Conceptualized the operationalization of decentralization through the CRE-MLG framework, which bridges policy design with local implementation. Provided actionable insights for enhancing</p>	<p>Academic Contribution:</p> <ul style="list-style-type: none"> Delivered a comprehensive governance framework detailing the 'how' of decentralization. Addressed critical knowledge gaps by synthesizing empirical and

and implementation strategies.		government involvement in energy governance is absent in this most recent policy.	citizen participation and accountability.	<p>conceptual insights into CRE governance in SSA.</p> <p>Policy Contribution:</p> <ul style="list-style-type: none"> • Provided policymakers with a roadmap for effective CRE adoption, grounded in real-world contexts and aligned with Nigeria's climate and development goals. • Facilitated an evidence-based approach to fostering sustainable energy transitions. • The roadmap operationalizes the Electricity Act (2023) by aligning national policy with local execution capacity (REDOs) and by targeting interventions where marginal adoption gains are highest per MNL/AME results.
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^a References to SSA are illustrative; claims are derived from Nigeria-specific data and transferability should be established empirically.

5.3 Result synthesis and implications of study

The findings of this thesis contribute significantly to the discourse on CRE in Northern Nigeria. By employing a sequential exploratory mixed-methods approach, the research systematically investigates the feasibility, barriers, and determinants of CRE adoption within the context of Nigeria's unique socio-political, economic and energy governance landscape.

5.3.1 Addressing the Literature Gap and Conceptual Contributions

As established in **Chapter 2**, existing CRE literature predominantly focuses on the Global North, offering limited insights applicable to SSA [20]. Some studies [21–23] emphasize the success factors of CRE projects in developed economies but fail to account for contextual differences such as governance frameworks, financial structures, and socio-cultural barriers unique to SSA. In contrast, this thesis identifies and addresses this gap by developing an alternative governance model that aligns with Nigeria's multi-tiered governance and socio-economic realities.

This research systematically explores the concept of CRE, its nuances, and its potential for the global energy transition, narrowing the focus to Nigeria's energy transition trajectory. Unlike previous studies that largely assess CRE as a technical solution to energy poverty, this thesis reframes CRE as a **governance challenge** in typical a SSA setting, emphasizing institutional structures, citizen engagement, and policy adaptation as key factors shaping CRE viability. To provide empirical context, **Chapter 2** conducted a chronological analysis of Nigeria's energy policies, tracing their evolution and identifying structural weaknesses that hinder decentralized renewable energy adoption. This analysis was supplemented with a comparative study of Germany and Denmark—two global exemplars of CRE implementation, identifying policy strategies that could be adapted to Nigeria's unique context.

However, while Germany and Denmark provide valuable lessons, direct replication is impractical due to fundamental differences in governance structures, institutional capacity, and socio-economic conditions (See Section 2.4.3). Unlike Germany's cooperative models, which thrive under strong regulatory backing and financial incentives, Nigeria lacks the institutional infrastructure and community investment frameworks necessary to replicate such initiatives. Instead, this thesis selectively adapts energy governance elements that align with Nigeria's existing structural

governance tiers of federal, state, and local government, which are successfully utilized in other sectors like health and education [24–28], but remain underutilized in the energy sector.

As a response to these challenges, this research develops the Community Renewable Energy–Multi-Level Governance (CRE-MLG) conceptual framework (Chapter 2), a novel governance model designed to operationalize CRE within Nigeria’s decentralized administrative structure (see Figure 2-3). The CRE-MLG Framework is a significant contribution to knowledge, providing a structured policy roadmap that delineates roles and responsibilities across governance tiers [29]. Unlike the centralized, top-down energy policies currently dominant in Nigeria, this **framework advocates for the institutionalization of REDOs at the local government level**. These officers serve as intermediaries, **bridging the gap between national energy policies and community-driven initiatives, ensuring policy coherence, and enhancing implementation effectiveness** (see Figure 2-3).

Beyond its theoretical grounding, the CRE-MLG conceptual framework was triangulated and empirically validated in **Chapter 4** through qualitative analysis, where key industry stakeholders strongly endorsed its feasibility. In particular, interview participants emphasized that the REDO model aligns with existing governance structures and could be institutionalized to drive localized energy planning and community participation. The fact that key informants—comprising policymakers, private sector representatives, an academic and community leaders—independently acknowledged the potentiality of REDOs reinforces the framework’s practical relevance and applicability. This convergence between conceptual development in **Chapter 2** and empirical validation in **Chapter 4** demonstrates that **the CRE-MLG framework can function as more than a theoretical construct by serving as an evidence-informed policy guide**.

While the CRE–MLG framework draws on foundational insights from the literature, it offers a novel governance perspective for decentralized renewable energy planning in Nigeria. Rather than positioning it as a universal solution, the framework serves as an exploratory model that integrates multi-level governance with community-led energy strategies. Although this research engages with broader SSA discourses, it does not

assume homogeneity across the region. Instead, it highlights the need for governance models to be context-sensitive and locally adaptable.

The CRE–MLG framework offers context-specific insights from Nigeria, which may offer transferable guidance—not generalizable conclusions—for countries in SSA facing similar governance challenges. In this regard, the framework is not presented as a definitive “paradigm shift” across the region, but rather as a locally grounded contribution that aims to broaden the conversation on inclusive and decentralized energy transitions in the global South. While country-specific, these insights may inform parts of SSA where institutional conditions are comparable; transferability should be established empirically.

However, while the framework provides important guidance for effective RE governance, its relevance to Nigeria may be constrained by local political dynamics, regulatory inconsistencies, and socio-economic factors. A careful examination of policy adaptability, stakeholder engagement mechanism, and administrative capacity is crucial to ensuring its successful implementation. Additionally, **Chapter 2** identifies several challenges, including bureaucratic inefficiencies, financing constraints, and regulatory inertia, that must be addressed to operationalize CRE effectively (See Table 5-1).

Ultimately, this research advances the discourse on CRE governance by offering a nuanced, context-specific framework for facilitating sustainable, decentralized energy transitions in Northern Nigeria. The CRE-MLG Framework not only delineates the roles of government and non-state actors in energy governance but also provides a practical policy tool for engaging communities in the global climate change mitigation agenda through sustainable energy adoption [30]. Additionally, it highlights the potential for citizen investment in and management of energy projects, ensuring equitable energy access, particularly for rural and underserved populations.

5.3.2 Empirical Validation: Quantitative and Qualitative Analysis

Chapters 3 and 4 undertook empirical investigations to validate the CRE-MLG Framework and assess its implementation potential through a two-fold mixed-method analysis. While Chapter 3 focused on identifying the socio-economic and governance determinants of CRE acceptance and adoption in Nigeria, Chapter 4 explored complementary insights from stakeholders on the institutional and policy environment.

Together, they provide critical evidence in a research area that remains underexplored in SSA, particularly regarding governance structures and citizen participation.

Quantitative Analysis: Determinants of CRE Adoption

The quantitative analysis in Chapter 3 (Objective 3a) provides robust empirical validation of the socio-economic and cognitive factors shaping CRE adoption in Northern Nigeria, using data from 559 households. The analysis employed a Multinomial Logit (MNL) model to capture non-linear dynamics and interaction effects, and results were interpreted through average marginal effects (AMEs) for clarity. This represents one of the few empirical studies to quantify layered drivers of citizen readiness for decentralized energy transitions in the region.

Key findings indicate that income is a critical determinant. Households with incomes 15–20% above the baseline were 33.9 percentage points more likely to commit to CRE adoption, and those exceeding 20% were 52.1 percentage points more likely (AME = 0.521, $p < 0.01$; Table 3-3). This confirms that affordability remains central, though the scale of investment in alternative energy, estimated at ~\$12 billion annually on generators [12,14,15,31,32], shows that citizens have latent capacity to redirect expenditure toward renewables if supported by policy and finance mechanisms.

Education and awareness were also decisive. Higher educational attainment significantly increased adoption likelihood (Table 3-3), while awareness alone boosted commitment by 14.7 percentage points (AME = 0.147; Table 3-2). However, interaction effects (Fig. 3-4) revealed nuanced patterns: awareness gains were strongest at lower and middle incomes but diminished at higher incomes, and education moderated awareness impacts. These results echo findings by Karakaya & Sriwannawit [33] and Balcombe et al. [34] that cognitive and informational drivers interact with socio-economic realities.

Occupation emerged as another key factor. Civil servants (+13.1 percentage points) and NGO workers (+11.4 percentage points) showed higher adoption probabilities than farmers and informal workers (Table 3-3), suggesting that occupational networks and organizational trust are important levers. Age and household size also mattered, with larger households and those aged 26–45 more likely to engage, while gender was not significant after controls, aligning with Conradie et al. [30].

The inclusion of interaction terms sharpened insights. Awareness $\times$ income was positive at moderate incomes ($\beta = 0.463$, $p < 0.1$) but negative at higher incomes ($\beta = -3.65$, $p < 0.01$; Table 3-3), indicating diminishing returns from generic awareness campaigns among affluent groups. Awareness $\times$ education produced mixed effects, suggesting the need for education-sensitive messaging and policy interventions. These findings validate the conceptual emphasis on layered determinants and reinforce that adoption pathways are context-specific and socially embedded [35,36].

These results demonstrate that adoption follows no simple linear path; rather, it reflects a combination of income, education, awareness, occupation, and institutional trust (see Tables 3-2, 3-3; Fig. 3-4). Awareness does not automatically translate to adoption; it interacts with affordability, schooling, and governance capacity. Where these are aligned, adoption probabilities rise; where they are absent, even strong awareness yields little action.

Overall, these results confirm that awareness is necessary but insufficient on its own; adoption is shaped by the interplay of economic capacity (income), cognitive access (education and awareness), and social embeddedness (occupation). In practical terms, the evidence calls for a segmented policy mix: (i) targeted financing for low- and lower-middle-income households, where the marginal gains in commitment are largest (Table 3-3; Fig. 3-4); (ii) education-sensitive and locally trusted awareness programmes, recognizing the moderating role of schooling on informational effects (Fig. 3-4); and (iii) occupation-routed outreach via civil service structures, NGOs and trader associations, reflecting the higher adoption probabilities observed among these groups (Table 3-3). At higher income levels—where awareness shows diminishing returns—policy emphasis should pivot from generic information provision to product quality assurance, finance terms, and reliability signals. Triangulation with qualitative insights in Chapter 4 supports these interpretations and highlights the value of local governance intermediaries (e.g., REDOs) to coordinate finance and information at the point of need. Model diagnostics reported in Chapter 3 (IIA checks and $VIF < 5$) further strengthen confidence in these conclusions, offering a grounded basis for governance-oriented, citizen-centered strategies to scale CRE in Nigeria.

These quantitative findings establish the socio-economic and cognitive contours of CRE adoption and set the stage for the qualitative insights that follow, exploring how

governance, institutions, and stakeholder dynamics interact with these household-level drivers.

Qualitative Analysis: Stakeholder Perspectives on Energy Governance

The second part of Objective 3 was addressed in Chapter 4, which provides an in-depth qualitative exploration of institutional challenges, policy gaps, and stakeholder engagement in CRE governance. Using thematic analysis of (n=15) state and non-state actor stakeholders across government tiers, private sector representatives, academics and community leaders, the study examined how governance arrangements and institutional trust shape the implementation and uptake of CRE. The qualitative findings complement the quantitative results by showing that even where economic and cognitive capacity exists, governance inefficiencies, political inertia, and limited local empowerment constrain adoption [37,38].

A key insight was the consistent endorsement of REDOs as an institutional mechanism. Participants echoed the need for structured local energy roles, validating the CRE-MLG framework proposed in Chapter 2. This finding links directly to the socio-economic patterns from Chapter 3: higher adoption among civil servants and NGO workers suggests trust and organizational proximity matter, which REDOs could leverage to bridge policy and practice [39]. Similarly, participants highlighted that local governments, despite being closest to citizens, lack the autonomy and resources to act. Embedding REDOs could enhance coordination, streamline approvals, and improve accountability.

Trust deficits also emerged as a recurring theme. Despite high private investment in off-grid energy solutions, many respondents cited lack of transparency and perceived government inefficiency as barriers. These qualitative themes mirror the quantitative emphasis on awareness needing reinforcement by trust and governance credibility. Stakeholders stressed that without transparent accountability structures and reliable policy frameworks, citizens remain cautious even when financially capable [37].

The combined insights from Chapters 3 and 4 therefore paint a coherent picture: CRE adoption is not solely an economic or informational challenge but also a governance one. Financial ability and awareness create potential, but institutional strength, trust, and proximity unlock it. These findings emphasize that Nigeria's CRE transition requires not just finance and technology but robust, decentralized governance

structures that empower local actors, backed by supportive national policy. This is the crucial bridge between the socio-economic drivers identified quantitatively and the institutional realities explored qualitatively, setting the stage for the synthesis in Section 5.3.3 and beyond.

5.4 Policy and Governance Implications

The findings of this thesis have significant implications for policy and practice, particularly in the context of energy governance, sustainable development, and climate justice in Nigeria and other SSA countries. By integrating CRE and MLG into a single conceptual framework, this research advances the understanding of how multi-tiered governance structures can be leveraged to address energy access challenges while ensuring social inclusion and environmental sustainability. The policy and governance implications of these findings are discussed below.

5.4.1 Decentralized Governance as a Catalyst for Energy Access

The evidence from Chapter 4 strongly supports the argument that decentralized governance is essential for accelerating energy access in Nigeria. The CRE-MLG framework proposes a decentralized approach that empowers LGs to play a leading role in implementing CRE. This approach enables localized energy solutions that are responsive to community needs, fostering adaptive governance practices capable of addressing emerging challenges more effectively.

Despite Nigeria's policy rhetoric on decentralization, energy governance remains highly centralized, limiting the ability of LGs to engage in meaningful energy planning and implementation. This research challenges this governance model, revealing that while the federal government retains central control over energy policies, LGs—being closer to the people—are best positioned to execute and manage localized CRE projects. However, as evidenced in **Chapter 4**, LGs lack institutional mechanisms, financial autonomy, and technical capacity to implement CRE effectively.

The validation of REDOs in Chapter 4 highlights the necessity of establishing formal institutional structures that bridge the gap between national energy policies and grassroots implementation. By institutionalizing REDOs, policymakers can facilitate intergovernmental coordination, enhance policy execution, and promote participatory governance, ensuring that CRE implementation aligns with regional energy needs.

5.4.2 Empowering Citizens as Co-Investors in Energy Solutions

This thesis highlights the significant financial commitment of Nigerian citizens to energy solutions, particularly through expenditures on hydrocarbon generators. With citizens already spending ~\$12 billion annually on generator fuel [12,17,40], there is clear evidence that households are willing to invest in reliable energy alternatives. However, existing policies fail to harness this financial commitment to drive CRE adoption. Rather than treating citizens as passive energy consumers, this research argues for policy innovations that reposition them as active co-investors in the energy transition process. This means that financial incentives should not merely focus on large-scale investors but should also provide household-level investment support, including:

- Subsidies for decentralized solar and wind energy installations.
- Tax incentives for small-scale renewable energy adopters.
- Community-based financing models, such as cooperative energy ownership, to lower entry barriers for lower-income households.

By enabling citizens to become prosumers [41,42], policymakers can leverage grassroots financial investments to complement public and private sector funding, thereby scaling up CRE deployment across Nigeria. This bottom-up approach aligns with international best practices where citizen-led energy cooperatives have successfully driven energy transitions in Germany and Denmark.

5.4.3 Addressing Energy Justice through a Phased Transition

The findings advocate for a phased approach to energy transition, recognizing Nigeria's economic dependence on fossil fuels for revenue, employment, and energy affordability. While renewable energy adoption is crucial for sustainability, an abrupt shift risks exacerbating energy poverty and disproportionately affecting low-income communities. This thesis contributes to the energy justice discourse by emphasizing the need for a just transition model that balances environmental, net zero emission, goals with socio-economic realities.

Empirical evidence from **Chapter 3** indicates that financial constraints remain a major barrier to CRE adoption, despite households collectively spending \$12 billion annually on hydrocarbon generators [12]. Results from stakeholder interviews presented in Chapter 4 further reveal that governance inefficiencies, policy misalignment, and lack

of financial support hinder renewable energy adoption more than financial incapacity. Policy makers must acknowledge these structural barriers and implement phased policy interventions to ensure an equitable transition.

Key recommendations include scaling up renewable energy infrastructure while gradually phasing out fossil fuel subsidies, ensuring targeted financing for low-income communities, and strengthening regulatory frameworks to support decentralized energy solutions. Additionally, aligning Nigeria's Electricity Act (2023) [43] with global energy justice principles [44,45] will help ensure a transition that is both socially inclusive and economically viable. A just transition must prioritize affordability, governance efficiency, and citizen participation to prevent deepening socio-economic disparities while advancing sustainable energy adoption.

5.4.4 Health and Policy Implications

Health externalities from fossil-fuel back-up generation strengthen the case for accelerating CRE adoption. Evidence from Nigeria links indoor air pollutants from generators to adverse outcomes among children, including impaired cognition and higher respiratory illness incidence [46]. In the context of our quantitative results, health-centered messaging should be targeted where awareness has the highest marginal returns—low- and lower-middle-income groups (see Table 3-3; Fig. 3-4). Generic awareness campaigns show diminishing returns at higher incomes; therefore, policy emphasis there should pivot to quality assurance, finance terms, and reliability signals rather than information alone.

Operationally, public health agencies can partner with REDOs to integrate clean-energy information into routine community health outreach, maternal and child health programmes, and school-based initiatives. Chapter 4 stakeholders emphasized that trusted local intermediaries and clear accountability improve uptake; embedding health messaging within REDO-coordinated outreach aligns with this insight [37,38]. Consistent with behavioral evidence, salient, near-term co-benefits—reduced smoke exposure, lower household medical costs—tend to motivate action more effectively than abstract environmental appeals [47]. By reframing CRE as a public-health necessity and an energy solution, policy can unlock adoption among groups that face both economic and informational constraints while maintaining credibility with higher-income households through product and performance guarantees.

5.4.5 Gender and Policy Implications for CRE Adoption

Women are central to household energy decisions in SSA yet face intersecting socio-economic and cultural barriers. Our quantitative analysis found gender was not a statistically significant predictor of adoption once income, education, awareness, and occupation were controlled for (see Table 3-3). This does not imply irrelevance; rather, it indicates that structural enablers (affordability, information access, institutional trust) explain more of the variance and should anchor policy design.

A gender-responsive approach should therefore focus on access and agency: (i) tailored micro-finance and pay-as-you-go products for women-led households and enterprises; (ii) targeted information via trusted local channels and women's associations coordinated by REDOs; (iii) capacity-building and leadership pathways that integrate women into local energy planning. Empirical studies report measurable gains when women participate directly in energy decisions [48] and highlight how gender intersects with income and education in shaping engagement with SHS and mini-grids [49]. Where women already leverage small-scale RETs for livelihoods, finance constraints limit scale; women-specific subsidies and revolving funds can shift them from consumers to prosumers [50].

Qualitative insights from Chapter 4 reinforce that trust in institutions and proximity of service matter for women's uptake. REDOs—positioned within local government but networked with health, social, and cooperative structures—can lower transaction costs, improve grievance redress, and build reliability signals that matter for first-time adopters [37,39]. Taken together, these measures align gender policy with the dominant quantitative levers (income, education, awareness, occupation) while addressing context-specific barriers identified qualitatively.

5.4.6 Strengthening Policy Coherence and Regulatory Frameworks

Grounded in the evidence, adoption is most responsive when affordability, education, and trusted delivery channels align (see Table 3-3; Fig. 3-4). Stakeholder interviews in Chapter 4 further stressed mandate clarity and proximate, accountable intermediaries. Policy coherence is therefore about reducing transaction costs and uncertainty for households and firms so that awareness and intent convert to real uptake.

The thesis identifies fragmented energy policies and regulatory inconsistencies as significant barriers to effective energy governance. Overlapping mandates between

federal, state, and local governments create bottlenecks, unclear roles, and weak enforcement. To address this, the CRE-MLG framework delineates roles and responsibilities across tiers. Policymakers should:

- Establish clear regulatory guidelines for CRE implementation at all governance levels.
- Streamline approval processes to eliminate bureaucratic inefficiencies.
- Ensure policy coherence between energy, environmental, and economic development objectives.

In practical terms, policy coherence is realized at the local level when Renewable Energy Desk Officers (REDOs) serve as licensing interfaces, consumer-protection touchpoints, and data-sharing conduits, ensuring that harmonized rules are credibly executed on the ground. This arrangement institutionalizes accountability and transparency through simple, auditable routines: (i) maintain a public register of CRE applications and status updates; (ii) publish monthly key performance indicators (time-to-approval, approvals/denials with standardized reasons, complaints received/resolved); (iii) act as first-line consumer-protection with published service standards (e.g., 10 working days to respond, 30 to resolve) and a defined escalation path; (iv) convene quarterly open forums with citizens and developers; (v) file quarterly datasets and narrative reports to the state energy desk; (vi) maintain auditable trails for licensing and vendor/installer accreditation; and (vii) coordinate basic quality-assurance checks for publicly supported projects. These disclosures (anonymized where needed) enable external scrutiny and performance tracking across LGAs.

To keep this practical and affordable, implementation is phased and scaled. Most LGAs begin with two to three core REDO roles—approvals/licensing, consumer protection, and data with targeted outreach—and expand to five to ten only in high-demand, urban, or project-dense LGAs as workload justifies. Where demand is low, functions are clustered across neighboring LGAs or covered by time-bound secondments from existing departments, with expansion tied to measured project pipeline and service-level performance. By harmonizing rules, publishing SLAs and fees, and running quality-assurance and grievance channels through REDOs, the framework reduces regulatory risk for firms, shortens cycle times for households, and gives lenders the predictability needed to underwrite projects.

5.4.7 Toward a Governance-Oriented Renewable Energy Transition

The transition is governance-oriented because constraints are less about attitude and more about rules, capabilities, and trust. The MNL results show diminishing returns to generic awareness at higher incomes and strong gains where finance and credible delivery are present (Table 3-3; Fig. 3-4), while Chapter 4 highlights the enabling role of clarified mandates and proximate institutions (REDOs).

The policy and governance implications of this study emphasize the urgent need for institutional restructuring, policy realignment, and financial innovation to facilitate CRE adoption in Nigeria. Governance inefficiencies and policy misalignment—not just financial constraints—pose the greatest challenge to scaling up RE solutions. By adopting a multi-level governance approach, strengthening institutional capacities, integrating financial mechanisms, and ensuring participatory governance, Nigeria can build a more resilient and inclusive energy future.

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6 CONCLUSION

6.1 Summary of Key Findings

This thesis investigated how decentralized governance and citizen participation can accelerate renewable energy (RE) adoption in Nigeria. Working within a Community Renewable Energy–Multi-Level Governance (CRE-MLG) framework, it identified barriers, enablers, and policy pathways for scaling decentralized energy. A sequential mixed-methods design integrated a quantitative household survey (Chapter 3) with stakeholder interviews (Chapter 4).

The evidence shows that governance inefficiencies—unclear mandates, weak local capacity, and limited accountability—remain the most persistent obstacles to adoption. At the same time, the quantitative analysis demonstrates that awareness alone is not sufficient: adoption rises where affordability, education, and trusted delivery channels are present. Using a multinomial logit (MNL) model interpreted through average marginal effects (AMEs), Chapter 3 finds that income, education, and awareness are the most consistent predictors of readiness, with occupation adding nuance (civil service/NGO workers more likely than informal workers). Interaction terms show diminishing returns to generic awareness at higher incomes and education-sensitive effects, reinforcing the need for targeted, context-specific interventions. Chapter 4 complements these results by revealing that institutional trust, proximity, and clear roles are decisive for converting intent into action.

Together, these findings support enacting measures to help drive a governance-oriented energy transition: one that couples finance and information with credible, local delivery mechanisms.

6.1.1 Theoretical Contributions

The thesis advances energy-governance scholarship by centering multi-level governance in a Sub-Saharan African (SSA) context. It demonstrates that decentralized, role-clear arrangements are not simply administrative choices but determinants of adoption. Empirically linking socio-economic drivers (income, education, awareness, occupation) to institutional capacity and trust extends existing theories beyond industrialized-country cases and provides an SSA-grounded account of how governance structure conditions household decisions.

6.1.2 Conceptual Contributions

A core contribution is the operationalization of the CRE-MLG framework through (REDOs embedded in local government. REDOs provide a concrete way to translate national policy into local execution by coordinating approvals, consumer protection, and information flows while building trust. More broadly, the study offers an Afrocentric perspective on CRE governance: it shows that the binding constraint is less a lack of willingness to pay and more the credibility and capability of institutions that channel citizen investment.

6.1.3 Empirical Contributions

This work provides one of the first large-sample, household-level examinations of CRE adoption dynamics in Northern Nigeria (n=559), conducted under ethical conditions and transparent reporting of methods (see Appendix C). The MNL results identify income, education, and awareness as key predictors, with occupation also important; gender is not significant once controls are included, while ages 26–45 and larger households show higher commitment. Interaction terms clarify that awareness is most productive at low- and lower-middle incomes and that education moderates its effect. These quantitative insights are triangulated with qualitative evidence from 15 state and non-state actors, which underscores the central role of clear mandates, proximity, and accountability in enabling adoption. Collectively, the data elevates governance from background context to primary mechanism.

6.2 Policy and Practitioner Contributions

6.2.1 Addressing Nigeria’s Energy Transition Plan (ETP 2022)

The Nigeria’s Energy Transition Plan (ETP) 2022⁸ estimates very large annual financing needs to 2060. The thesis points to an under-used domestic lever: the substantial private spending currently devoted to back-up fossil-fuel generation can be re-channeled toward decentralized renewables when credible governance and finance are in place. By deploying the CRE-MLG architecture and institutionalizing REDOs, government can create a trust-based financing pathway that blends targeted subsidies, micro-finance/pay-as-you-go products, and community co-investment. This

⁸ <https://www.energytransition.gov.ng/>

improves energy security, reduces emissions, and aligns citizen investment with national targets.

6.2.2 Strengthening Policy Coherence

Policy fragmentation and regulatory inconsistency raise transaction costs and deter both households and firms. The CRE-MLG framework provides a roadmap for harmonizing rules and clarifying roles across federal, state, and local tiers. Standardized procedures, transparent licensing, consumer-protection norms, and interoperable data practices should be coordinated through REDOs so that coherence at the center yields credible execution where adoption actually occurs.

6.2.3 Enhancing Citizen Participation and Financial Trust

Citizens demonstrate willingness to invest when delivery is reliable, and institutions are trustworthy. Strengthening participation therefore requires transparent oversight, complaint-handling and redress mechanisms, targeted and education-sensitive information campaigns, and financial tools matched to household cash-flows. Locally situated REDOs can convene these elements, lowering uncertainty and turning awareness and intent into uptake.

6.3 Limitations of Research

The analysis is centered on Northern Nigeria; while many governance patterns are shared across SSA, generalization should be cautious. Survey-based methods can be affected by response biases, and the quantitative design is predominantly cross-sectional, limiting causal inference. Because the survey minimized open-ended fields to preserve standardization and timing in multi-LGA fieldwork, some nuance is left to the qualitative strand; we mitigated this by triangulating survey patterns with interview evidence (Chapter 4). Finally, policy feasibility depends on political will and institutional capacity, which vary by jurisdiction and over time. These limitations do not undermine the findings but set boundaries for interpretation. Also, the qualitative sample did not include national energy NGOs; we focused on statutory implementers. Future research will purposively include NGO actors to deepen the civil-society perspective on delivery and accountability

6.4 Recommendations for Future Research

Further work should test the CRE-MLG approach across diverse SSA settings to assess transferability and adaptation. Longitudinal or panel designs would help track

transition pathways from awareness to participation and measure durability of adoption. Implementation research and piloting of REDO offices could evaluate cost-effectiveness, accountability, and citizen experience on a scale. Experimental or quasi-experimental studies should examine which combinations of finance instruments (e.g., micro-loans, guarantees) and information strategies (health-centered, reliability-centered, education-sensitive) deliver the largest marginal gains for specific income and occupation segments. Finally, future work could deepen analysis of financial trust and risk perceptions, cooperative ownership models, and distributional impacts to ensure a just transition.

In conclusion, this thesis demonstrates that Nigeria's pathway to decentralized renewables is fundamentally governance oriented. Adoption increases where affordability, education, and credible, proximate institutions align. The CRE-MLG framework and the REDO mechanism translate national ambition into local capability, turning private willingness to pay into real projects. By aligning policies with local realities and empowering citizens as informed co-investors, Nigeria can build an energy system that is more reliable, more inclusive, and better aligned with its climate and development goals. The evidence and proposals here offer a practical, citizen-centered alternative to centralized paradigms and contribute to a wider conversation about energy justice and sustainable development in Sub-Saharan Africa.

APPENDICES

Appendix A

Appendix A1: Variable Coding and Crosswalk

Descriptive category (Table 2)	Model category
Charity / NGO	Civil Service
Civil servant	Civil service
Private Company	Private sector
Self-employed artisan	Trading
Self-employed farmer	Farming
Sel-employed trader	Trading
Student	Other
Retired	Other
Unemployed	Unemployed
Housewife	Other
Housing association	Other
Religious organization	Other
Cooperatives	Other

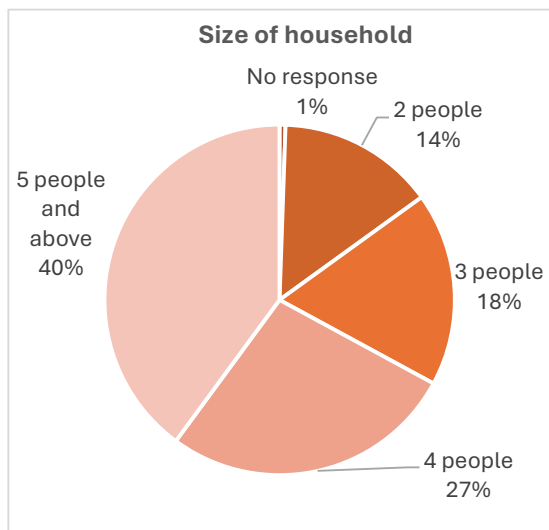
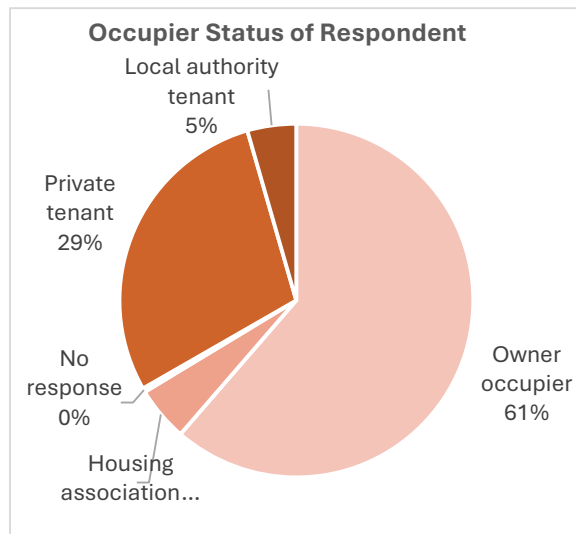
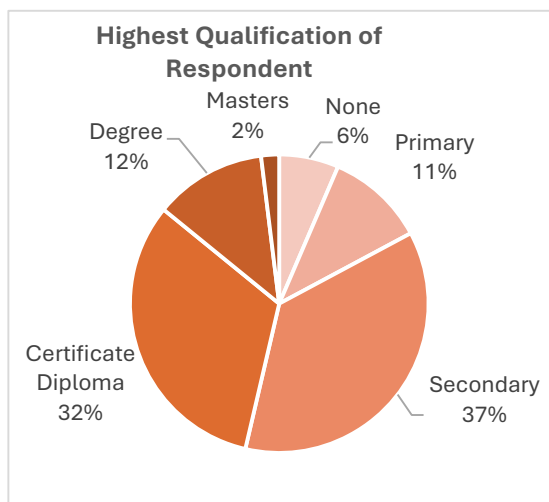
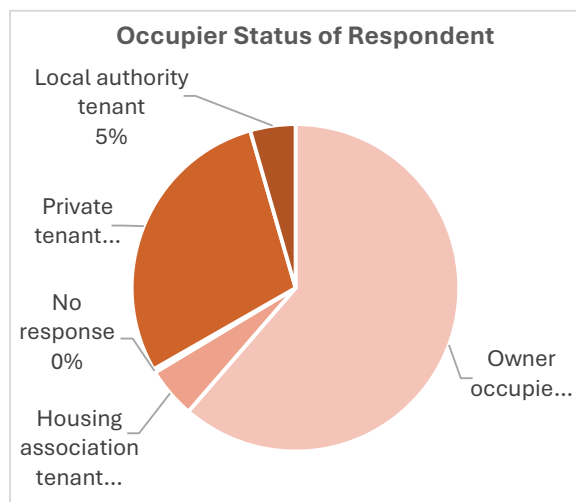
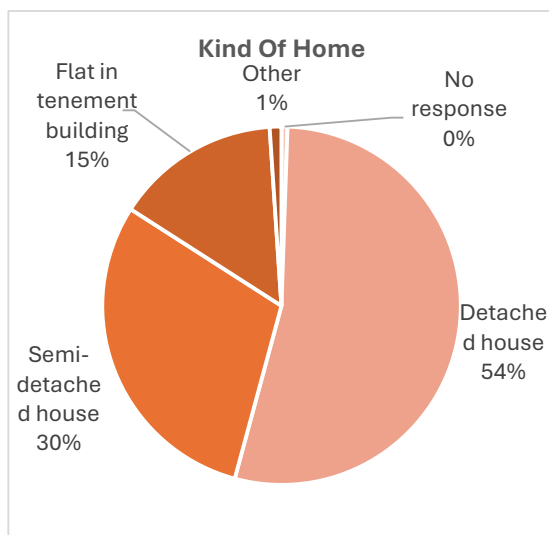
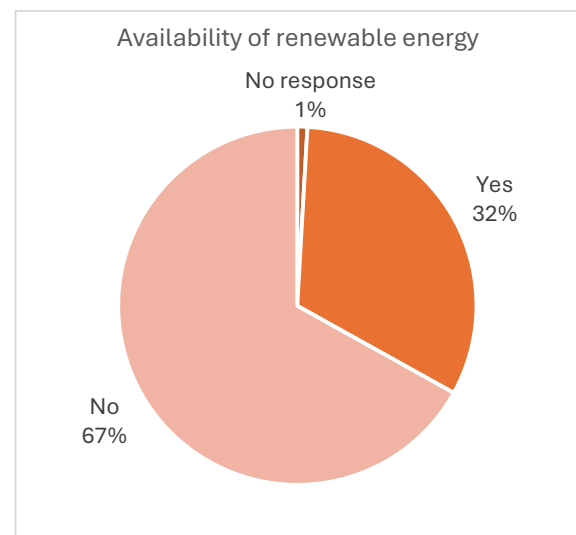
Appendix A2. Sample composition

Expanded Table 1, Survey Sample size

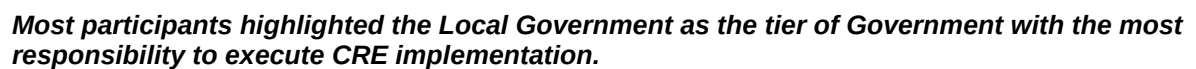
State	Population Size (household)	Proportion(%)of Population	Stratified Sample Size
North-East			
Bauchi			
Alkaleri	234	3%	23
Ganjuwa	334	6%	32
Misau	285	5%	27
Gombe			
Akko	284	5%	27
Dukku	290	5%	28
Shomgom	332	6%	32
North-Central			
Plateau			
Barkin Ladi	386	7%	37
Kanam	283	5%	27
Pankshin	335	6%	31
Nassarawa			
Akwanga	430	7%	41
Kokona	308	5%	29
Wamba	261	4%	25
North-West			
Jigawa			
Auyo	272	5%	26
Gagarawa	328	6%	31
Hadejia	381	6%	36
Kano			
Ajingi	436	7%	42
Dala	339	6%	33
Gabasawa	332	6%	32
Total	5850	100%	559

Source: Pilot survey 2006

Appendix A3: Education and Household Demographics



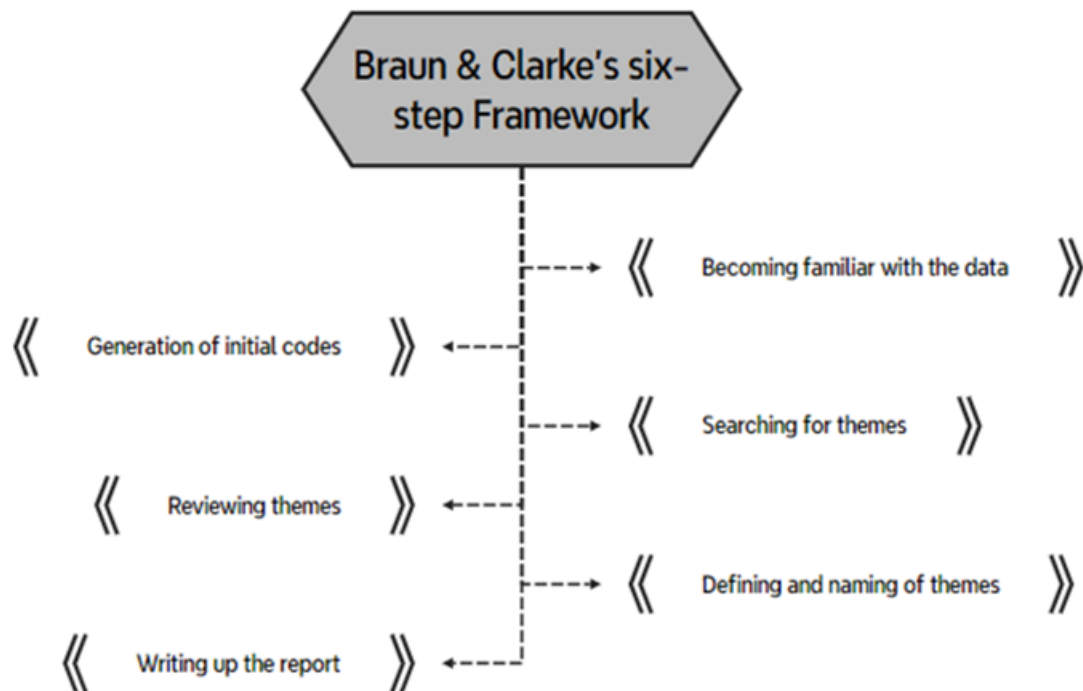
Appendix B1: Word Cloud of Stakeholder Perspectives on Local Government and CRE Implementation



Appendix B2: Interview Excerpts that advocate for a homogenous energy office at Local Government level.

<p>“There are many energy agencies domiciled in Abuja. All they need to do is harmonize an office and decentralize them to all the LGs nationwide. Especially, REA. We need to amend the Act that establishes it by expanding its scope so all the communities in remote areas feel its impact”</p> <p>IP-07</p>	<p>“There should be an amalgamation of all these energy offices integrated into one desk or office at LG levels” –IP03</p>	<p>“LGs should have the same thing, the way they have education or health agencies domiciled in all LGs, energy offices should have the same in LGs. For instance, the REA should be decentralized, rather than being central, or a liaison officer at state (mid-govt) level and then officers in every LG. Afterall the ‘R’ in the acronym means rural but there is no single office of them in rural communities”</p> <p>IP-14</p>
<p>“By having the local governments execute energy duties for federal government agencies. Don't you see how other federal government agencies structure their offices down here and achieve their programmes in all communities of the country with local government partnerships? Like Ministry of education's free education and ministry of health immunization and vaccination programmes”. - IP07</p>	<p>“We need to have representation of the rural electrification implementing agencies and the regulatory agency within all the local government structures like some government offices at the local government level. 1. to bring awareness, 2. to guide and support coordination”</p> <p>IP-12</p>	<p>“The local government can play a significant role in assisting to bring data and information that reflects the true position of an un-electrified community and their willingness to pay. The only thing is that the people themselves cannot get this type of data and so can only depend on the local government to get somebody who has the capacity, skills or technical knowledge to gather the kind of data that is required. This encourages transition to renewable energy”</p> <p>-IP01</p>
<p>“Just like how we have the security civil defense offices in local governments, so there should be a NERC desk officer in each local government, who will listen to & liaise with the people, and of course, they shouldn't be paid by the local government if not they would compromise, as long as the local government is behaving the way it is.” – IP12</p>	<p>“The local government chairman should be fully aware of any energy project in his domain, and he should have an officer who knows something technical about energy that will tell him all that is happening because the chairman is a politician and may not have an idea of what the complex energy is all about but with somebody by his side, as maybe an energy officer who will be relating with the state, federal as well as with the chairman, I think helps”</p> <p>-IP15</p>	<p>“By appointing desk officers that are called focal persons. They should be called focal persons in states and then the states also appoint focal persons in the local government. Whatever is happening in the federal government, the state will be carried along as well as the local government” -IP-06</p>

Appendix B3: Braun and Clarke's six-step framework for thematic analysis.



Appendix C

Appendix C1: Ethical Approval Letter



23 October 2021

Dear Mr Kaze ,

Reference: CURES/14741/2021

Title: The Local Government policy role in the implementation of community renewable energy projects in Nigeria: An exploration of the Multi-Level Governance (MLG) approach

Thank you for your application to the Cranfield University Research Ethics System (CURES).

We are pleased to inform you your CURES application, reference CURES/14741/2021 has been reviewed. You may now proceed with the research activities you have sought approval for.

If you have any queries, please contact CURES Support.

We wish you every success with your project.

Regards,

CURES Team

Appendix C2: Supplementary information on surveys and interviews



DATE:JULY 2022

MULTI-LEVEL GOVERNANCE (MLG) FRAMEWORK IN IMPLEMENTING COMMUNITY RENEWABLE ENERGY (CRE) PROJECTS IN NIGERIA

PART A: INTRODUCTION

Thank you for taking the time to participate in this study. I am a doctoral researcher conducting important research on the Multi-Level Governance (MLG) Framework for implementing Community Renewable Energy (CRE) projects in Nigeria. This study aims to explore how multi-level governance structures can create enabling conditions for the effective and sustained adoption of CRE. Additionally, it seeks to understand how citizen participation can play a transformative role in Nigeria's renewable energy transition, recognizing that public engagement is crucial to the success of energy reforms.

This research involves one-on-one interviews with participants selected based on their expertise and experience in renewable energy governance in Nigeria. Participants include key state and political actors from federal, state, and local government levels, senior public officials in the energy sector, and private-sector stakeholders actively engaged in renewable energy initiatives.

The primary objective of this interview is to gain insights into the social dimensions of CRE adoption, assess public acceptance of renewable energy as an alternative source, and explore the roles of government actors at different levels in ensuring the successful implementation of CRE under the MLG framework.

The interview is expected to take approximately 35 minutes. Your participation is voluntary, and you may withdraw at any time.

PART B: RESEARCH CODE OF CONDUCT

As a Cranfield researcher, I adhere to strict ethical guidelines:

Confidentiality – Your contact details will be securely stored and will not be shared with anyone.

Anonymity – Findings will be reported in a way that ensures participants remain unidentified.

Consent – To proceed, please review and complete the consent form.

For further information or any questions regarding this research, please feel free to contact me, Kim Kaze, at k.kaze@cranfield.ac.uk.

Thank you for your time. I look forward to your valuable insights



Appendix C3: Participant consent sheet

Part 1: Consent to Participate and Right to Withdraw

I confirm that I have been fully informed about this research project and voluntarily agree to participate.

I understand that all personal information I provide will be treated confidentially, and my name will not appear in any report, publication, or presentation.

The researcher(s) will assign a participant number instead of recording my name. The file linking my name to this number will be accessible only to the main researchers and will be securely destroyed after 30th November 2021.

I understand that I can withdraw from the study at any time by notifying a member of the research team (contact details provided).

I understand that I can request the withdrawal of my data for up to three months from today. After this period, my individual data will no longer be identifiable within the aggregated results, as explained in point 3.

Part 2: Security of Data Storage

I understand that my data will be used solely for research purposes by Cranfield University.

The data will be stored on the University's secure network, accessible only to authorized personnel, in compliance with the UK Data Protection Act 2018.

Part 3: Data Handling and Future Use

Survey responses will be saved as text files and securely deleted once they are no longer required.

Analytical software will be used to aggregate results, and all reasonable measures will be taken to anonymize the data.

Final Confirmation

I confirm that:

- I understand that the aggregated data will be published in support of the research findings.
- I understand that the final analysis will be published in support of the research findings.
- I have read and understand this information and consent to participating in this research.



Appendix C4: Participant Information

Survey Number:	Survey Date:	
Name of Respondent (optional)		
Years in industry:	Gender: (Please tick as appropriate)	<ul style="list-style-type: none"> • Male • Female • Prefer not to say
State Stakeholders:	Name of Organization	
Politicians: <ul style="list-style-type: none"> • Minister • Legislator <ul style="list-style-type: none"> ➤ Senator ➤ Representative • Commissioner • Local Government Chairman • Director General/CEO • Attorney-General Office 		
Federal Government Public Institutions (Level 15 and above)		
<ul style="list-style-type: none"> • Permanent secretary • Director • Head of Unit • Municipal officers 		
Non-state actors	Name of Organization	
<ul style="list-style-type: none"> • Proprietor • Investor • NGO Chief executive • Community Based Organization President • Project leader • Chair of Trust • Project developer • Steering group member • Member of organizations providing support for CRE schemes • RET Vendor 		

Interview Start Time:	
Interview End Time:	

Appendix C5: Interview Questionnaire

Community renewable energy (CRE) is a term used to describe citizens' engagement, participation, and cooperation through collective action in the development of energy transition infrastructure at local level. A crucial component of CRE is the community's active engagement in the conception, ownership, decision-making, and/or management of the energy projects, which places citizens and communities at the center of renewable energy generation (as fully engaged actors).

PART D: INTERVIEW QUESTIONS I

1. In what ways do you think local government in Nigeria can play an important role in the country's local energy development? Please suggest the type(s) of energy governance that might influence local renewable energy policy in this regard. If No. Please state why
2. How do you think the federal, state and local governments can work together to help support the development of CRE in Nigeria?
3. What role do you think fund availability, steady policy framework and increased RE capacity/knowledge transfer play in enabling CRE?
4. Promoting citizen engagement is shown to deliver a number of benefits below. Which of these (in no particular order) do you think are the top three (3) most important for Nigeria?
 - a) improving awareness of climate change
 - b) boosting the local economy through money generated locally
 - c) encouraging behavioral change for energy conservation
 - d) lowering emissions directly
 - e) economic empowerment
5. What RET will deliver the most benefits for average households/SME in Nigeria
 - a) solar PV power
 - b) Wind
 - c) Biomass
 - d) Hydro
6. How much will you recommend an average household should give up supporting a subsidized CRE entry Level (11-50W) Solar Home System-SHS project in a typical Nigerian community. Given that the majority of people in rural communities and even metropolitan regions earn between US\$1 to US\$10 per day per capita in purchasing power parity terms?
7. Select and discuss mitigation strategies of top three (3) obstacles to CRE adoption in Nigeria in order of importance.
 - a) Inadequate technology
 - b) Lack of skilled labour for maintenance
 - c) Lack of spare parts availability
 - d) High cost
 - e) Difficulty obtaining credit
 - f) Poor purchasing power
 - g) Unfair energy pricing

- h) Lack of knowledge or awareness
 - i) Lack of adequate training on CRE system operation and maintenance.
8. Select the top three (3) drivers for CRE adoption in Nigeria in order of importance, and comment on them.
- a) Long-term supportive policies
 - b) Suitable regulatory environment
 - c) Financial incentives (soft loans, grants, and capital subsidies to users)
 - d) Removal of current subsidies for fossil fuels
 - e) The development of specialised institutions
 - f) Collaboration with international agencies
 - g) The active involvement of local communities in CRE
 - h) Creation of public awareness about CRE

INTERVIEW QUESTIONS II

9. Based on relevant background/experience

s/n	Background of Actors	Question
a.	Legislator, Federal Law Maker /Top Politician	What role as a lawmaker or politician can you play in drafting enabling legislation that is CRE-friendly?
b.	Senior Federal Government Executive/State Actor	What other roles can you play as a senior federal government official to promote CRE adoption? What impact do federal policies have on CRE development, and what adjustments could be required to encourage CRE adoption going forward?
c.	Senior State Government Executive	As a senior state executive, what part do you envision the state government playing in the adoption of CRE in your state? Discuss
d.	Senior Local Government Executive/Chairman	As a senior local government executive, what role do you think the local government can play in the adoption of CRE in your municipality? Discuss

10. Which level of government should be granted the most responsibility to implement CRE in Nigerian communities, in your opinion, based on your experience?

1=least suited; 5=most suited (Please tick as appropriate)

	1	2	3	4	5
--	---	---	---	---	---

Federal government					
State government					
Local government					

11b. Based on your response to question 11a, what institutional or regulatory authorities do you feel should be statutorily added to the level of government you identified as most suitable for implementing CRE?

12. As a (Please tick as appropriate)

RET Vendor	Community Chief	Association President	NGO/Advocacy executive	Community Leader	Energy agency senior executive
------------	-----------------	-----------------------	------------------------	------------------	--------------------------------

What role do you think your organisation can play in the adoption of CRE in Nigeria?

13. What are the most crucial policy steps the government must take to guarantee that citizens are included in the successful transition from a fossil-reliant to a low-carbon efficient economy,

14. Do you feel Nigeria's prior renewable energy policies are on track to meet Sustainable Development Goals (SDG)7s objective of "ensuring access to cheap, dependable, sustainable, and modern power for everyone" by the 2030 deadline, including urban and rural residents?

- Yes (Discuss the policies that are on track)
- No (Discuss the loopholes policies that are hinderances)

15. How do you assess the following indicators as benefits of CRE and motivating factors for CRE growth in Nigeria? (Discuss them)

	Highly significant	Moderately significant	Significant	Less significant	Not significant
Financial/economic benefits					
Ease energy poverty for households					
Increased social inclusion					
Behavioural benefit; change agent for a more sustainable lifestyle					

16. Which of the following do you consider to be the most significant barriers to overcome for the successful take-off of Community Renewable energy in Nigeria? (Discuss)

	Highly significant	Moderately significant	Significant	Less significant	Not significant
Scepticism about CRE/NIMBY opposition					
Lack of Political commitment/support for CRE					
Lack of effective policy, legal and institutional framework					
Process of awarding projects					
Stakeholder co-operation					
Planning & implementation					
Organisational issues/legal framework					
Lack of skilled expertise/Maintenance					
Public acceptance & inclusion.					
Poor funding/lack of resources					
Poor stakeholder engagement					

17. What impact has Nigeria's energy policies have had a substantial influence on alleviating energy poverty throughout the years, given that the country's peak capacity output in 2022 is less than the extremely inadequate 5,000MW of intermittent supply?

18. How do you think the federal government of Nigeria has excluded local government from (being involved in) energy policy development? (the level of government closest to the citizens) And therefore, Nigeria's energy policies over the years have had a little impact on reducing energy poverty?

Strongly agree	Agree	Moderately Agree	Disagree	Strongly disagree

19. What role do you think citizens can play in renewable energy development in Nigeria?.....

Appendix C6: Participant Information and Consent for Survey Questionnaire



Introduction

This research is conducted by **Kim Del Kaze**, a PhD researcher in Energy and Power at Cranfield University. This survey is part of his doctoral dissertation titled:

“Multi-Level Governance (MLG) Framework in Implementing Community Renewable Energy (CRE) Projects in Nigeria.”

The study seeks to identify the conditions under which multilevel governance provides a favorable framework for the sustained implementation of community renewable energy (CRE) projects in Nigeria. It also explores how citizen participation can drive energy transitions and contribute to the successful adoption of renewable energy solutions. The research assumes that active public engagement is essential for achieving long-term sustainability in Nigeria's energy sector.

This survey questionnaire consists of six key sections:

Household Demographics: Basic socio-economic characteristics.

Renewable Energy Awareness: Knowledge and familiarity with renewable energy options.

Renewable Energy Technologies and Willingness to Pay: Understanding household preferences and affordability.

Community Participation: Social attitudes toward cooperative energy initiatives.

Perceptions of Government Intervention: Views on policies, regulations, and governance.

Barriers and Drivers to CRE Adoption in Nigeria: Factors influencing the adoption of renewable energy.

The primary objective of this survey is to gain insights into the social aspects of CRE adoption, the likelihood of public acceptance, and the role of governance actors at different levels in enabling successful CRE implementation under the MLG framework.

The questionnaire will take approximately 25 minutes to complete. Your participation is entirely voluntary, and you may withdraw at any time without providing a reason.

Research Code of Conduct

As a Cranfield University researcher, I adhere to strict ethical standards:

Confidentiality – Your contact details will be securely stored for the duration of the research and will not be shared with any third party.

Anonymity – Survey responses will be analyzed in aggregated form, and no individual participant will be identifiable in the findings.

For Further Inquiries – If you have any questions regarding your participation in this PhD research, please contact: Mr. Kim Del Kaze – Email: k.kaze@cranfield.ac.uk

Thank you for your time and valuable input. Your participation is crucial in shaping policies for sustainable energy development in Nigeria.

Appendix C7: Interviewee Information



Survey Number:	Survey Date:	
Name of Respondent (optional)		
Age:	Gender: (Please tick as appropriate)	<ul style="list-style-type: none"> • Male • Female • Prefer not to say
Name of Community:		
District:		
Local Government:		
State:		
Estimated population in community		

Interview Start Time:	
Interview End Time:	

SECTION I: HOUSEHOLD DEMOGRAPHICS

(Please tick as appropriate)				
Marital Status				
Single	Married	Divorced	Widowed	Others (please Specify)
Average Income:	Nil	Low	Middle	High
Which of this best represent the organization for which you work? (Tick one)	Charity/non-for-profit/ volunteer group	Housing provider (plus social housing)	Community interest organization	Government employee
	University/academia	Non-Governmental Organization (NGO)	Health/social worker (excluding LG employee)	Local Government/Council employee
	Small-Scale Enterprise	Artisans (plumbers, tailors, masons,	Farmers	Others (Please specify)

		carpenters etc)		
Highest Qualification level (Tick one)	None	Primary	Secondary	Certificate
	Diploma	Degree	Masters	Doctoral
What kind of home do you live in?	Detached house	Semi- detached house	Flat in tenement building	Other (Please specify)
Which of the following categories applies to you?	Owner occupier	Private tenant	Housing Association tenant	Local Authority tenant
Size of household (tick all that apply)	2	3	4	More than 4 (please state)
Who is your current electricity supplier?	Grid (please specify the name)	Off-Grid (please specify the name)	Personal (self- generated)	
What is the major item/activity that consumes energy in your household the most? (You can tick more than 1)	Light bulbs for clearer vision	TV and radio; Charging electronic gadgets /devices	Home appliances like fans, storage (fridge), room heaters, iron, water heaters	Others (please specify)
Do you have low energy light bulbs in your home? (Please tick)	All	Some	None	
How often do you turn off the heating?	Almost always	Very often	Not very often	
How often do you turn the heating				
Do you already have any of the	Renewable energy generation (e.g.,	Energy efficiency measures	Solar powered heater	Other energy related

following at your home (tick all that apply)?	solar PV on your roof)			improvements e.g., inverters
In the past year, what was the availability of your energy source like? (Please tick	A. Always available	B. Mostly available	C. Sometimes available	D. Seldom available E. Never available F. Do not know.

SECTION II: RENEWABLE ENERGY AWARENESS

1. Do you know what a renewable energy is?

- a. Yes
- b. No (Please go to question 3)

1.1 If you responded "Yes" to the question above, please explain its benefits vis-à-vis how it differs from the traditional energy you are accustomed to using.

.....

.....

.....

.....

.....

.....

2. Given your understanding of renewable energy, how likely are you to advice that it should be used in your community?

1 =least likely; 5=very likely

1	2	3	4	5
---	---	---	---	---

3. Do you know that renewable energy sources like the sun, wind, rivers, and biomass can be an alternative energy source from the conventional energy source you know?

- a. Yes
- b. No

3.1 On a scale from 1 to 5, how important is it to protect the environment? 1 = lowest; 5 = highest (please tick) * **Use Likert scale here**

1	2	3	4	5
---	---	---	---	---

Community renewable energy (CRE) is a term used to describe citizens' engagement, cooperation and participation through collective action in the development of energy transition infrastructure at local level. A crucial component of CRE is the community's active engagement in the conception, ownership, decision-making, and/or management of the energy projects, which places citizens and communities at the centre of renewable energy generation (as fully engaged actors).

1. Do you know that the use of CRE can help reduce indoor/outdoor pollution?

YES	NO	DON'T KNOW
-----	----	---------------

2. Based on your current knowledge of renewable energy and its benefits, what is your level of support for CRE?

1 =least supportive; 5=very supportive

1	2	3	4	5
---	---	---	---	---

3. Please indicate agreement to the following statements:

1 =least agree; 5=strongly agree

1	2	3	4	5
---	---	---	---	---

- Each of us has a role to play in reducing climate change.
- Renewable energy sources are limitless.
- The finest sources of energy are fossil fuels.
- Renewable energy use should be encouraged with significant incentives.
- Gas is better for the environment than coal.
- The transition to renewable energy is critical to the development of the local economy.
- Current national efforts to reduce climate change are insufficient

4. With the understanding of CRE, will you be interested in CRE?

1=not interested; 5=highly interested

1	2	3	4	5
---	---	---	---	---

5. What will be your main motivation for your interest in CRE (tick all that apply)

- a. Climate emergency – reduce carbon emissions
- b. Save money on energy bills
- c. Have more reliable energy supply
- d. Become more self-sufficient
- e. Make a return on investment
- f. Generate income for the community

- g. All of these
- h. Other (please specify)

--

**SECTION
III**

RENEWABLE ENERGY TECHNOLOGY AND ABILITY TO PAY

6. How much thought do you give to saving energy in your home?

1=Not so much thought; 5=Highly thoughtful

1	2	3	4	5
---	---	---	---	---

7. What renewable energy technologies do you consider most viable for your community, i.e., which options would you be most interested in (tick all that apply)?

- a. Solar PV Panels on Community Buildings
- b. Solar PV Panels on Residential Buildings
- c. Small Solar Farm
- d. Small Scale Distributive Wind Turbines
- e. Others (please specify)

8. If a renewable energy technology is developed in your community, what type of contribution would you make? (Please tick as appropriate)

Financial	
Planning	
Paid labor	
Volunteering	
Others	

9. Would you like to substitute your current energy system with any renewable energy technology of your choice?

- a. Yes
- b. No

- I. If Yes (please tick most suitable)

- i. Solar PV
- ii. Solar Home Systems
- iii. Biofuels
- iv. Community Wind Energy
- v. Others (please specify)

II. If No (please state why).....

10. How concerned are you about the price of renewable energy compared to the existing electricity grid price?

1 =least concerned; 5=very concerned

1	2	3	4	5
---	---	---	---	---

11. What is your average monthly income?.....
(optional)

12. How much of your monthly income are you willing to spend on a sustainable community renewable energy supply? Please circle an option below

0%	5%	10%	15%	20%	25%	30%
----	----	-----	-----	-----	-----	-----

13. The cost of community renewable energy in your neighbourhood could be marginally greater than the price of the centralized grid system or hydrocarbon-powered generators.

Would you be prepared to pay more to protect your health and the environment?

1 =Low willingness; 5=Extremely willingness

1	2	3	4	5
---	---	---	---	---

14. What amount of energy does your household consume? (Please tick) ***N.B. Will explain where needed**

- a. Portable system (0-3W)
- b. Multi light systems (3-11W)
- c. Entry Level Solar Home System (11-50W)
- d. Don't Know

SECTION IV:	COMMUNITY PARTICIPATION
--------------------	--------------------------------

Community renewable energy (CRE) is a term used to describe citizens' engagement, participation, and cooperation through collective action in the development of energy transition infrastructure at local level. A crucial component of CRE is the community's active engagement in the conception, ownership, decision-making, and/or management of the energy projects, which places citizens and communities at the centre of renewable energy generation (as fully engaged actors).

15. Considering the above statement, on a scale from 1 to 5, How would you rate your ability to cooperate and collaborate?

1 = lowest; 5 = highest (please tick)

1	2	3	4	5
---	---	---	---	---

16. Would you be in favour (support) of your community replacing carbon intensive energy systems with a community renewable energy project?

1 =least interested; 5=very interested

1	2	3	4	5
---	---	---	---	---

17. Would you participate if your community decided to establish a community renewable energy cooperative/club/association?

If yes, please tick your level of commitment. 1 = lowest; 5 = highest (please tick)

1	2	3	4	5
---	---	---	---	---

18. What will be your level of commitment if your community decided to adopt CRE?

1 =least committed; 5=highly committed

1	2	3	4	5
---	---	---	---	---

19. Do you agree that the implementation of Community renewable energy would enhance revenue for the local community?

YES	NO
-----	----

20. How would you prefer the ownership of the CRE project to be structured? (Please tick)

Entirely community owned	
Utility owned	
Entirely privately owned	
Externally owned	
Mixed ownership	
Other:	

21. What stakeholders would you like to see represented on the CRE project? (You can tick more than one box)

Stakeholder(s)
Community Based Organization
NGO
Govt Body
Traditional Authority
Religious Authority
School Representatives
Youth Group Reps
Others (mention)

22. What level of involvement do you think these stakeholders should have?

Stakeholder(s)	1-5 (1=Least involved; 5=highly involved)
Community Based Organization	
NGO	
Govt Body	
Traditional Authority	
School Representatives	
Youth Group Reps	
Others (mention)	

23. Would you be interested in investing in a community owned energy asset?

- a. Yes
- b. No
- c. Maybe
- d. Undecided

SECTION V: GOVERNMENT INTERVENTION

24. Should the government continue to subsidize fossil fuel or transition to renewable energy?

1=less urgently transit; 5=urgently transit **Use Likert scale here*

1	2	3	4	5
---	---	---	---	---

25. Do you believe that government subsidies for renewable energy are likely?

1 =least likely; 5=very likely

1	2	3	4	5
---	---	---	---	---

26. If a feasibility study about the viability of what renewable energy technologies for your community were undertaken, which options would most interest you?

- a. Low carbon transportation (cars, green buses)
- b. Heating/Cooling sources (cooking, water heaters, room heaters, ACs/fans, fridges)
- c. Shared Solar Roof PVs

- d. Shared Solar+ storage with options to feed the grid for revenue generation for the community
- e. Community owned renewable energy technology (large or medium scale, please specify)

27. Do you think government intervention can lower the energy price?

- a. Yes
- b. No
- c. Don't know

28. If yes, how? (Please tick all that apply) If No (Please state why)

.....

- a. Subsidy
- b. Grant
- c. loan
- d. tax incentives

29. Which level of government do you trust is most suited to implementing CRE in your community? 1=least trusted; 4=most trusted (please tick as appropriate)

	1	2	3	4	5	Do not know
Federal government						
State government						
Local government						

30. Do you think government intervention (subsidies, loans, grants, tax incentives) can increase your interest in Community renewable energy?

- a. Yes
- b. No
- c. Do not know

34. To what extent do you believe the following are a disincentive to the development of renewable energy in Nigeria's rural areas? (On a scale of 1-5, with one being the lowest and 5, the highest)

- a. It is expensive
- b. The rate of return on investment is quite slow.
- c. The technology has the potential to become obsolete very quickly.
- d. There is a scarcity of knowledge about renewable energy sources.

- e. Entrenched political interests

SECTION VI: BARRIERS AND DRIVERS

35. DRIVERS

How do you rate the following as drivers of CRE development in your local community?

	Strongly Agree	Tend to Agree	Tend to Disagree	Strongly Disagree
Financial/economic benefits				
Ethical and environmental commitment				
Co-ownership (control) of Community renewable energy projects				
Opportunity for new jobs				
Easing energy poverty for households				
Government subsidies (e.g. loans and grant)				
Local income generation				
Behavioral benefit; change agent for a more sustainable lifestyle				
Increased social inclusion				

36. BARRIERS

How do you rate the following as barriers for CRE development in your local community?

	Strongly Agree	Tend to Agree	Tend to Disagree	Strongly Disagree
High cost of RETs				
Lack of effective policy, legal and				

institutional framework				
Poor awareness				
Poor tax relief, subsidies and loans				
Poor stakeholder engagement				
Skepticism (NIMBY)				

SUPPLEMENTARY INFORMATION (S1-S3)

Supplementary Note 1: STATA Estimation Commands and Syntax

```
. import excel "C:\Users\Desktop\KIM\QYM.xlsx", sheet("Sheet1") firstrow
. recode sex (1=1 "Male") (0=0 "Female"), generate(sex_cat)
(0 differences between sex and sex_cat)
. recode marital_status (1=1 "Married") (2=2 "Single") (3=3 "Widow_Widower"),
generate(status)
(0 differences between marital_status and status)
. recode awareness (1=1 "Yes") (0=0 "No"), generate(aware)
(0 differences between awareness and aware)
. recode house_size (1=1 "2 People") (2=2 "3 People") (3=3 "4 People") (4=4 "At least 5
People"), generate(size)
(0 differences between house_size and size)
. recode income (1=1 "Less than 5") (2=2 "Between 5 and 9") (3=3 "Between 10 and 14")
(4=4 "Between 15 and 20") (5=5 "Greater than 20"), generate(incom)
(0 differences between income and incom)
. recode education (1=1 "None") (2=2 "Primary") (3=3 "Secondary") (4=4 "Diploma") (5=5
"Degree") (6=6 "Masters"), generate(edu)
(0 differences between education and edu)
. recode occupation (1=1 "Charity") (2=2 "Housing") (3=3 "Community") (4=4 "Government")
(5=5 "Academia") (6=6 "NGO") (7=7
> "Health") (8=8 "LG") (9=9 "Small Scale") (10=10 "Artisan") (11=11 "Farmers") (12=12
"Others"), generate(occu)
(0 differences between occupation and occu)
. recode interviewer (0=0 "Ishaku") (1=1 "Michael") (2=2 "Igwe") (3=3 "Francis") (4=4
"Simon") (5=5 "Njengo") (6=6 "Yasir")
> (7=7 "Sani") (8=8 "Abdulsalam") (9=9 "Kabiru") (10=10 "Bashar") (11=11 "Muhammad")
(12=12 "Felix") (13=13 "Mato") (14=14
> "Yeipeng") (15=15 "Dadung") (16=16 "Akor") (17=17 "Kingsley"), generate(interview)
(0 differences between interviewer and interview)
```

```

. recode education (1=1 "Not Committed") (2=2 "Slightly Committed") (3=3 "Moderately
Committed") (4=4 "Committed") (5=5 "Hi
> ghly Committed"), generate(adoptions)

(0 differences between education and adoptions)

. recode adoption (1=1 "Not Committed") (2=2 "Slightly Committed") (3=3 "Moderately
Committed") (4=4 "Committed") (5=5 "Hig
> hly Committed"), generate(adoptions)

. recode adoption (1=1 "Not Committed") (2=2 "Slightly Committed") (3=3 "Moderately
Committed") (4=4 "Committed") (5=5 "Hig
> hly Committed"), generate(adoptionss)

(0 differences between adoption and adoptionss)

use "C:\Users\DR KIM\Desktop\KIM\LATEST.dta", clear

mlogit adoption age i.sex_cat i.status i.occu i.edu i.size i.aware i.incom i.inter, vce(robust)

margins, dydx(age) predict(outcome(5)) nofvlabel

margins, dydx(i.sex_cat) predict(outcome(5)) nofvlabel

margins, dydx(i.status) predict(outcome(5)) nofvlabel

margins, dydx(i.occu) predict(outcome(5)) nofvlabel

margins, dydx(i.edu) predict(outcome(5)) nofvlabel

margins, dydx(i.size) predict(outcome(5)) nofvlabel

margins, dydx(i.incom) predict(outcome(5)) nofvlabel

margins, dydx(i.inter) predict(outcome(5)) nofvlabel

mlogit adoption age i.sex_cat i.status i.occu i.edu i.size i.aware i.incom i.inter i.aware#i.edu,
vce(robust)

. margins, dydx(age) nofvlabel

. margins, dydx(i.sex_cat) nofvlabel

. margins, dydx(i.status) nofvlabel

. margins, dydx(i.occu) nofvlabel

. margins, dydx(i.edu) nofvlabel

. margins, dydx(i.size) nofvlabel

. margins, dydx(i.incom) nofvlabel

. margins, dydx(i.inter) nofvlabel

mlogit adoption age i.sex_cat i.status i.occu i.edu i.size i.aware i.incom i.inter
i.aware#i.incom, vce(robust)

```

```
regress age i.sex_cat status occu edu size i.aware incom inter
```

```
. estat vif
```

```
mlogit adoption age i.sex_cat i.status i.occu i.edu i.size i.aware i.incom i.inter  
i.aware#i.incom, vce(cluster lga)
```

```
marginsplot, title("Marginal Effect of Age on High Adoption", size(medium)) xtitle("Age  
(years)", size(medium)) ytitle("Predicted Probability of High Adoption", size(medium))  
xlabel(10(10)80, labsize(medium)) ylabel(, labsize(medium) format(%9.2f))  
plotopts(lcolor(blue) mcolor(blue) msymbol(O)) ciopts(lcolor(gray) size(small))  
scheme(s2color)
```

```
marginsplot, title("Marginal Effect of Awareness on High Adoption", size(medium))  
xtitle("Awareness", size(medium)) ytitle("Predicted Probability of High Adoption",  
size(medium)) xlabel(1 "Yes" 0 "No", labsize(medium)) ylabel(, labsize(medium)  
format(%9.2f)) plotopts(lcolor(blue) mcolor(blue) msymbol(O)) ciopts(lcolor(gray)) size(small))  
scheme(s2color)
```

```
marginsplot, title("Marginal Effect of Marital Status on High Adoption", size(medium))  
xtitle("Marital Status ", size(medium)) ytitle("Predicted Probability of High Adoption",  
size(medium)) xlabel(1 "Married" 2 "Single" 3 "Widow_Widower" , labsize(medium)) ylabel(  
labsize(medium) format(%9.2f)) plotopts(lcolor(blue) mcolor(blue) msymbol(O))  
ciopts(lcolor(gray)) size(small)) scheme(s2color)
```

```
marginsplot, title("Marginal Effect of Occupation on High Adoption", size(medium))  
xtitle("Occupation", size(medium)) ytitle("Predicted Probability of High Adoption",  
size(medium)) xlabel(1 "Charity" 2 "Housing" 3 "Community" 4 "Government" 5 "Academia"  
6 "NGO" 7 "Health" 8 "LG" 9 "Small Scale" 10 "Artisan" 11 "Farmers" 12 "Others",  
labsize(medium)) ylabel(, labsize(medium) format(%9.2f)) plotopts(lcolor(blue) mcolor(blue)  
msymbol(O)) ciopts(lcolor(gray)) size(small)) scheme(s2color)
```

```
marginsplot, title("Marginal Effect of Level of Income on High Adoption", size(medium))  
xtitle("Level of Income", size(medium)) ytitle("Predicted Probability of High Adoption",  
size(medium)) xlabel(1 "Less than 5 Percent" 2 "Between 5 and 9 Percent" 3 "Between 10  
and 14 Percent" 4 "Between 15 and 20 Percent " 5 "Greater than 20", labsize(medium))  
ylabel(, labsize(medium) format(%9.2f)) plotopts(lcolor(blue) mcolor(blue) msymbol(O))  
ciopts(lcolor(gray)) size(small)) scheme(s2color)
```

```
marginsplot, title("Marginal Effect of Size of Household on High Adoption", size(medium))  
xtitle("Size of Household", size(medium)) ytitle("Predicted Probability of High Adoption",  
size(medium)) xlabel(1 "2 People" 2 "3 People" 3 "4 People" 4 "At least 5 People" 5 "Degree"  
6 "Masters", labsize(medium)) ylabel(, labsize(medium) format(%9.2f)) plotopts(lcolor(blue)  
mcolor(blue) msymbol(O)) ciopts(lcolor(gray)) size(small)) scheme(s2color)
```

Supplementary Note 2: Full MNL Regression Outputs

	Robust					
adoption	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
-----+-----						
age	.0059797	.0125085	0.48	0.633	-.0185365	.030496
sex_cat						
Male	.0389984	.2272935	0.17	0.864	-.4064887	.4844854
status						
Single	-.143408	.2494806	-0.57	0.565	-.6323809	.345565
Widow_Widower	.5125768	.3947826	1.30	0.194	-.2611828	1.286337
occu						
Housing	-2.307305	.7448733	-3.10	0.002	-3.76723	-.8473803
Community	-1.226468	.8466441	-1.45	0.147	-2.88586	.4329239
Government	-1.351037	.6653689	-2.03	0.042	-2.655136	-.0469377
Academia	-.4856566	.7865897	-0.62	0.537	-2.027344	1.056031
NGO	-.9259083	.7346512	-1.26	0.208	-2.365798	.5139816
Health	-1.715803	.7562086	-2.27	0.023	-3.197945	-.2336615
LG	-.5260338	.7176648	-0.73	0.464	-1.932631	.8805633
Small Scale	-1.195679	.6628996	-1.80	0.071	-2.494938	.1035803
Artisan	-1.161147	.6914132	-1.68	0.093	-2.516292	.1939984
Farmers	-1.246104	.6868263	-1.81	0.070	-2.592259	.1000512
Others	-1.050777	.7432163	-1.41	0.157	-2.507454	.4059001
edu						
Primary	.7257762	.5436222	1.34	0.182	-.3397038	1.791256
Secondary	.494623	.4985438	0.99	0.321	-.4825049	1.471751

Diploma	.4950488	.5027425	0.98	0.325	-.4903085	1.480406
Degree	.6378459	.591474	1.08	0.281	-.5214219	1.797114
Masters	.333649	.821198	0.41	0.685	-1.275869	1.943167
size						
3 People	-.0322978	.3273526	-0.10	0.921	-.6738971	.6093014
4 People	.1533208	.3054571	0.50	0.616	-.4453641	.7520057
At least 5 People	.4893189	.3070611	1.59	0.111	-.1125098	1.091148
aware						
Yes	.6265773	.2417653	2.59	0.010	.152726	1.100429
incom						
Between 5 and 9	.6735758	.2933627	2.30	0.022	.0985955	1.248556
Between 10 and 14	1.066487	.3575891	2.98	0.003	.3656254	1.767349
Between 15 and 20	2.243551	.6242433	3.59	0.000	1.020057	3.467045
Greater than 20	2.612878	.6822393	3.83	0.000	1.275713	3.950042
inter						
2	1.327788	.882339	1.50	0.132	-.401565	3.05714
3	1.336473	.841236	1.59	0.112	-.3123196	2.985265
4	-.0159956	.8908871	-0.02	0.986	-1.762102	1.730111
5	3.345891	.9776854	3.42	0.001	1.429663	5.262119
6	1.440102	.9429279	1.53	0.127	-.4080023	3.288207
7	.16493	.9407872	0.18	0.861	-1.678979	2.008839
8	2.621372	1.045002	2.51	0.012	.5732061	4.669539
9	1.667637	.9775527	1.71	0.088	-.2483309	3.583605
10	1.910581	.9489376	2.01	0.044	.0506977	3.770465
11	1.14479	.9718711	1.18	0.239	-.7600427	3.049622
12	2.877957	.9053839	3.18	0.001	1.103438	4.652477
13	2.293354	.8981616	2.55	0.011	.5329901	4.053719
14	1.614885	.9235415	1.75	0.080	-.195223	3.424993

15	2.073127	.9118512	2.27	0.023	.2859314	3.860322
16	1.355065	.9098006	1.49	0.136	-.4281115	3.138241
17	1.336118	.8988033	1.49	0.137	-.4255042	3.09774
18	2.375319	.9142756	2.60	0.009	.5833721	4.167267

```
-----
|               Robust
adoption |   Coef. Std. Err.   z   P>|z|   [95% Conf. Interval]
-----+-----
age |   .0045901   .0124817   0.37  0.713   -.0198735   .0290537
|
sex_cat |
Male |   .0071205   .2317589   0.03  0.975   -.4471187   .4613596
|
status |
Single |  -.1334599   .2514915  -0.53  0.596   -.6263741   .3594544
Widow_Widower |   .5448634   .392595   1.39  0.165   -.2246088   1.314336
|
occu |
Housing | -2.175377   .7554456  -2.88  0.004   -3.656023   -.694731
Community | -1.091763   .8551986  -1.28  0.202   -2.767921   .5843958
Government | -1.192452   .6685147  -1.78  0.074   -2.502716   .1178131
Academia |  -.348897   .7954089  -0.44  0.661   -1.90787   1.210076
NGO |  -.7906426   .7404984  -1.07  0.286   -2.241993   .6607075
Health | -1.691346   .7590329  -2.23  0.026   -3.179023   -.2036686
LG |  -.3955684   .7202188  -0.55  0.583   -1.807171   1.016034
Small Scale | -1.029717   .669938   -1.54  0.124   -2.342771   .2833377
Artisan |  -.9826557   .6997791  -1.40  0.160   -2.354198   .3888861
Farmers | -1.073967   .6933061  -1.55  0.121   -2.432822   .2848877
Others |  -.868752   .7525354  -1.15  0.248   -2.343694   .6061904
|
edu |
Primary |   1.30557   .6984099   1.87  0.062   -.0632886   2.674428
```

Secondary		1.183027	.6629992	1.78	0.074	-.1164281	2.482481
Diploma		1.217504	.6836051	1.78	0.075	-.1223377	2.557345
Degree		1.385372	.9478483	1.46	0.144	-.4723764	3.243121
Masters		-.416476	.8806831	-0.47	0.636	-2.142583	1.309631
size							
3 People		-.0318254	.3273047	-0.10	0.923	-.6733308	.6096799
4 People		.1956615	.3120337	0.63	0.531	-.4159134	.8072363
At least 5 People		.544893	.3153313	1.73	0.084	-.073145	1.162931
aware							
Yes		2.279566	.7811295	2.92	0.004	.7485799	3.810551
incom							
Between 5 and 9		.6548818	.2963442	2.21	0.027	.0740577	1.235706
Between 10 and 14		1.079795	.3613299	2.99	0.003	.3716013	1.787988
Between 15 and 20		2.304368	.6295635	3.66	0.000	1.070446	3.53829
Greater than 20		2.609368	.6840736	3.81	0.000	1.268609	3.950128
inter							
2		1.394558	.8577436	1.63	0.104	-.2865885	3.075705
3		1.352357	.8225681	1.64	0.100	-.2598469	2.964561
4		-.0750694	.8707282	-0.09	0.931	-1.781665	1.631526
5		3.394397	.9764552	3.48	0.001	1.48058	5.308214
6		1.48783	.9264013	1.61	0.108	-.3278827	3.303544
7		.1921062	.9141579	0.21	0.834	-1.59961	1.983823
8		2.757628	1.038152	2.66	0.008	.7228884	4.792368
9		1.696062	.9660367	1.76	0.079	-.1973353	3.589459
10		1.921152	.9292146	2.07	0.039	.099925	3.742379
11		1.063899	.9460871	1.12	0.261	-.790398	2.918195
12		2.997431	.895593	3.35	0.001	1.242101	4.752762
13		2.265409	.8833773	2.56	0.010	.5340208	3.996796

14		1.629747	.9045659	1.80	0.072	-.1431691	3.402664
15		2.087391	.8983155	2.32	0.020	.3267246	3.848057
16		1.368259	.8950363	1.53	0.126	-.3859799	3.122498
17		1.34069	.8788407	1.53	0.127	-.3818059	3.063186
18		2.417137	.9004846	2.68	0.007	.6522198	4.182055
aware#edu							
Yes#Primary		-1.533787	.9192519	-1.67	0.095	-3.335488	.2679131
Yes#Secondary		-1.795151	.8326157	-2.16	0.031	-3.427048	-.1632544
Yes#Diploma		-1.790438	.8192907	-2.19	0.029	-3.396219	-.184658
Yes#Degree		-1.770062	1.035597	-1.71	0.087	-3.799795	.2596717
Yes#Masters		-.0549783	1.247028	-0.04	0.965	-2.499107	2.389151
-----+-----							

Robust							
adoption		Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
-----+-----							
age		.0028034	.0128394	0.22	0.827	-.0223613	.0279681
sex_cat							
Male		.0544516	.227854	0.24	0.811	-.3921341	.5010373
status							
Single		-.1270934	.2498084	-0.51	0.611	-.6167088	.3625219
Widow_Widower		.5499717	.396641	1.39	0.166	-.2274303	1.327374
occu							
Housing		-2.416557	.7632247	-3.17	0.002	-3.91245	-.9206645
Community		-1.266775	.8451751	-1.50	0.134	-2.923288	.3897376
Government		-1.538585	.6836027	-2.25	0.024	-2.878422	-.1987486
Academia		-.6760431	.8059551	-0.84	0.402	-2.255686	.9035998
NGO		-1.118406	.7427974	-1.51	0.132	-2.574262	.3374498

Health	-1.888731	.7753559	-2.44	0.015	-3.408401	-.3690617
LG	-.7336891	.7384955	-0.99	0.320	-2.181114	.7137354
Small Scale	-1.381858	.6891676	-2.01	0.045	-2.732602	-.0311145
Artisan	-1.325259	.7098443	-1.87	0.062	-2.716528	.0660101
Farmers	-1.446656	.701843	-2.06	0.039	-2.822243	-.0710689
Others	-1.303447	.758964	-1.72	0.086	-2.790989	.1840952
edu						
Primary	.7172212	.552607	1.30	0.194	-.3658686	1.800311
Secondary	.4330346	.4994969	0.87	0.386	-.5459612	1.41203
Diploma	.4402899	.5053203	0.87	0.384	-.5501197	1.4307
Degree	.6137138	.5906425	1.04	0.299	-.5439242	1.771352
Masters	.4444391	.8209639	0.54	0.588	-1.164621	2.053499
size						
3 People	.0045264	.3284657	0.01	0.989	-.6392545	.6483073
4 People	.1648009	.3036577	0.54	0.587	-.4303573	.7599591
At least 5 People	.5439016	.3025553	1.80	0.072	-.049096	1.136899
aware						
Yes	1.209644	.4627971	2.61	0.009	.3025788	2.11671
incom						
Between 5 and 9	1.185926	.4729778	2.51	0.012	.2589066	2.112945
Between 10 and 14	1.347281	.5773537	2.33	0.020	.2156888	2.478874
Between 15 and 20	3.180034	.7880366	4.04	0.000	1.63551	4.724557
Greater than 20	14.13755	1.429654	9.89	0.000	11.33548	16.93962
inter						
2	1.242931	.8950173	1.39	0.165	-.5112706	2.997133
3	1.014971	.883989	1.15	0.251	-.7176154	2.747558
4	-.3542992	.9615352	-0.37	0.713	-2.238874	1.530275

5		3.111838	1.002715	3.10	0.002	1.146552	5.077124
6		1.083452	1.025525	1.06	0.291	-.9265398	3.093443
7		.0320742	.9670305	0.03	0.974	-1.863271	1.927419
8		2.274469	1.083649	2.10	0.036	.1505559	4.398383
9		1.528791	.9871953	1.55	0.121	-.4060764	3.463658
10		1.825858	.9713404	1.88	0.060	-.077934	3.72965
11		.8212007	1.029434	0.80	0.425	-1.196452	2.838853
12		2.48772	.9706522	2.56	0.010	.5852766	4.390163
13		1.969339	.9496721	2.07	0.038	.1080164	3.830663
14		1.453319	.9492902	1.53	0.126	-.4072551	3.313894
15		1.91768	.942663	2.03	0.042	.0700948	3.765266
16		1.143775	.941977	1.21	0.225	-.7024663	2.990016
17		1.0776	.9382588	1.15	0.251	-.7613536	2.916553
18		2.202078	.9385183	2.35	0.019	.3626161	4.04154

|

aware#incom |

Yes#Between 5 and 9		-.8896494	.5504193	-1.62	0.106	-1.968451	.1891525
Yes#Between 10 and 14		-.5048683	.6830473	-0.74	0.460	-1.843616	.8338799
Yes#Between 15 and 20		-1.690274	1.085776	-1.56	0.120	-3.818357	.4378082
Yes#Greater than 20		-11.95724	1.581001	-7.56	0.000	-15.05594	-8.858533

-----+-----

/cut1		-3.610639	1.321601			-6.20093	-1.020349
/cut2		-2.170755	1.27982			-4.679156	.3376462
/cut3		.7507606	1.277068			-1.752247	3.253768
/cut4		3.896702	1.305561			1.337849	6.455555

Supplementary Note 3: Marginal Effects and Diagnostic Outputs

Average marginal effects Number of obs = 537

Model VCE : Robust

-----+-----						
	Delta-method					
	dy/dx	Std. Err.	z	P> z	[95% Conf. Interval]	
-----+-----						
1.incom	(base outcome)					
-----+-----						
2.incom						
	_predict					
1		-.0053474	.0034743	-1.54	0.124	-.0121569 .001462
2		-.0136735	.0077201	-1.77	0.077	-.0288046 .0014576
3		-.0854556	.038944	-2.19	0.028	-.1617844 -.0091267
4		.0194341	.0161785	1.20	0.230	-.0122753 .0511434
5		.0850424	.0343686	2.47	0.013	.0176812 .1524037
-----+-----						
3.incom						
	_predict					
1		-.0072049	.0041531	-1.73	0.083	-.0153448 .000935
2		-.018845	.0084488	-2.23	0.026	-.0354044 -.0022857
3		-.1276843	.0429408	-2.97	0.003	-.2118467 -.0435219
4		.006124	.0200463	0.31	0.760	-.033166 .0454141
5		.1476101	.0494685	2.98	0.003	.0506536 .2445667
-----+-----						
4.incom						
	_predict					
1		-.0099223	.0050888	-1.95	0.051	-.0198961 .0000515
2		-.0269019	.0097542	-2.76	0.006	-.0460197 -.0077841
3		-.2162399	.0462746	-4.67	0.000	-.3069364 -.1255435

4	-.1190972	.0758682	-1.57	0.116	-.2677962	.0296017
5	.3721613	.1111948	3.35	0.001	.1542235	.5900991

-----+-----

5.incom |

_predict |

1	-.0103006	.0053226	-1.94	0.053	-.0207327	.0001314
2	-.0280762	.0098317	-2.86	0.004	-.0473458	-.0088065
3	-.2335335	.0439254	-5.32	0.000	-.3196257	-.1474414
4	-.1727953	.0935378	-1.85	0.065	-.356126	.0105354
5	.4447056	.1250065	3.56	0.000	.1996975	.6897138

Note: dy/dx for factor levels is the discrete change from the base level.

Pseudo R2 = 0.1745

Pseudo R2 = 0.1790

Pseudo R2 = 0.1790