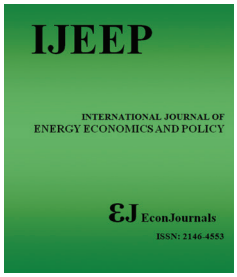

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External Actors in Nigeria's Solar Energy Transition: A Comparative Analysis of Multinational Corporations, International Organizations, and State-Led Investors

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ABSTRACT

The shift to renewable energy development in fossil fuel-rich developing countries such as Nigeria, is usually influenced by complex interaction among external actors, regulatory frameworks, and entrenched fossil fuel interests. However, how the effectiveness of different types of external actors - international organizations, multinational corporations, and state-led investors – differs, remains unknown. The Nigeria Electrification Project, Ashama Solar Power Plant, and Kaduna Solar Power Project are selected for comparative case study analysis. Using the Multi-Level Perspective framework, the study examines how niche innovations, socio-technical regime, and landscape pressures affect solar energy transition in Nigeria. The findings demonstrate that international organizations-led solar projects have facilitated decentralized electrification but faced with financial sustainability issues; multinational corporations-led projects have driven large-scale installation yet encountered regulatory and market risks; by contrast, state-led projects have exhibited superior stability benefiting from strong government backing and state investor's geopolitical alignments. Nonetheless, there are also challenges that impede Nigeria's long-term renewable energy development, such as inconsistent policies, fossil fuel subsidies, and macroeconomic volatility. Therefore, this study highlights the need for a hybrid investment approach that integrates the advantages of each type of external actors while tackling structural barriers. This study provides broader insights to similar fossil fuel-rich developing economies.

Keywords: Solar Energy Transition, External Actors, Policy and Regulation, Fossil Fuel-Rich Developing Economies
JEL Classifications: Q42, Q48, F21, O13

1. INTRODUCTION

The global transition to renewable energy (RE) is gaining momentum as countries try to lower their reliance on fossil fuels and lessen climate change (IEA, 2022). Technological advancements, declining costs, and international climate commitments have driven this shift (IRENA, 2023). In addition to institutional obstacles, rooted hydrocarbon interests, and an increased reliance on oil and gas exports, fossil fuel-rich economies like Nigeria face several challenges due to the transition to renewable energy (Chinagorom et al., 2023). Nigeria's transition to renewable energy is slow because fossil fuels dominate domestic energy consumption and export revenues despite having a sizable solar energy potential (IEA, 2022). While policies like the Renewable Energy Master Plan exist, structural constraints have hindered significant progress (Federal Ministry of Power, 2024).

Energy diversification is a politically and economically sensitive because of Nigeria's fossil fuel exports, which account for more than 85 % of the government's income (World Bank, 2025). Due to conflicting political and private sector interests in hydrocarbons, insufficient grid infrastructure, limited financing, and inconsistent policy implementation, large-scale solar energy adoption is a significant challenge (Ebhota and Jen, 2020). There is still a lack

of widespread integration into Nigeria's energy mix despite the rise of off-grid and mini-grid solar solutions (Sovacool, 2021). Additionally, institutional capacity constraints and inconsistent policy frameworks weaken the country's capacity to implement and sustain an RE transition (Okoh and Okpanachi, 2023).

Moreover, few studies have focused on comparing the role of different external actors - such as multinational corporations (MNCs), international organizations (IOs), and state-led investors - in Nigeria's RE transition, despite existing research has primarily examined the role of MNCs and IOs in RE development (Aklin and Urpelainen, 2018). In particular no study, to our knowledge, has considered the role of state-led investors – particularly China – which are expanding through direct investments, infrastructure projects, and technology transfer (Chen et al., 2024). China's participation in Nigeria's energy transition is growing, but its effectiveness is hampered by domestic regulatory complexity, policy uncertainty, and fossil fuel interests (Gungah et al., 2019).

To overcome this problem, in the following sections the Multi-Level Perspective (MLP) is demonstrated as the core theoretical framework to explore the external actor involvement in fossil fuel-rich economies (Geels, 2002). The MLP conceptualizes energy transitions as interactions between niche level, social-technical regime level, and landscape level. Although MLP framework has been widely applied to research regarding energy transitions, its application to external actors remains unstudied. The MLP framework has been rectified in this study by examining how different external actors interact within and across the three levels in Nigeria's solar energy transition.

For this study, it was of interest to investigate whether state-led investors will exert greater influence than MNCs and IOs in fossil fuel-rich Nigeria's solar energy transition. The aim of this study is to compare the role of MNCs, IOs, and state-led investors in Nigeria's solar energy transition, and to explore what factors shape their effectiveness. This study will contribute to the broader literature on energy governance, sustainability, and international investment in RE, and providing more insights into the influence of different type of external actors in shaping developing country's RE development, particularly with fossil fuel-rich context.

2. LITERATURE REVIEW

2.1. Solar Energy Transition: Current Trends and Issues

Due to lower costs and growing international support, solar energy has become central to the shift towards RE in developing economies (IRENA, 2023). However, shift paths vary depending on economic structures, institutional frameworks, and energy policies. While India and Brazil have expanded solar energy through government-led initiatives and private-sector involvement (Carstens and Cunha, 2019; Ferreira et al., 2018; Kar et al., 2016; Rathore et al., 2018; Sharma et al., 2012), Nigeria still faces structural challenges (Agbo et al., 2021; Ogunmodimu and Okoroigwe, 2019), including policy inconsistencies, financial constraints, and infrastructure deficits.

Three broad approaches to solar energy transition - state-led, market-driven, and hybrid approaches - are frequently used by developing countries (IRENA, 2023). There are studies pointing out that state-led renewable energy transitions, exemplified by China and India, greatly depend on government subsidies, policy mandate, and national solar missions to boost expansion (Hayashi, 2020; Khosla et al., 2020). These countries have benefited from strong institutional framework, centralized energy policies, and strategic investments in solar manufacturing. Competitive bidding, private sector involvement, and minimal state intervention are highlighted in market-driven RE transitions, as seen in countries like Chile and South Africa (Ahjum and Lawrence, 2023; Nasirov et al., 2018; Soumonni and Ojah, 2022). Hybrid approaches combining public and private sector engagement, are exemplified by countries such as Brazil and Morocco, where state-backed financial instruments and auction-based systems facilitate private investment (Bradshaw, 2017; Pereira et al., 2012; Vidican, 2015; Werner and Lazaro, 2023).

Solar energy initiatives in developing countries are often undermined by weak institutional capacity, conflicting policy frameworks, and restricted access to funding. Kenya and Ghana are two examples of African countries that have benefited from international organizations-backed mini-grid initiatives to increase solar-powered energy access in rural areas (Amankwah-Amoah and Sarpong, 2016; George et al., 2019; Mugisha et al., 2021; Steel et al., 2016). However, Nigeria's dependence on fossil fuel export revenues and inconsistent RE policies have tempered its large-scale solar deployment. Integration into the national grid remains limited, despite mini-grid projects have expanded through international organizations-funded programs such as the initiatives from Rural Electrification Agency (Chanchangi et al., 2023; Ebhota and Jen, 2020; Olujobi et al., 2023).

Additionally, external actors play a crucial role in addressing these issues by providing financial investments, technical assistance, and policy support. International organizations and state-led investors have encouraged large-scale solar-powered projects in a few African and Asian countries through concessional financing and capacity-building initiatives (Aly et al., 2019; Geall et al., 2018; Otsuki, 2017). However, the effectiveness of the external actor's involvement varies. Concerns over debt sustainability and project execution have still been remained in China's investment in Ethiopia and Kenya, regardless of how rapid development in those countries' solar infrastructure it has enabled (Addis et al., 2020; Monyae and Chapotera, 2023; Onjala, 2018). Similarly, international organizations such as World Bank and the African Development Bank, have advanced policy reforms to encourage private sector investment (Anyanwu, 2006; Arezki and Sy, 2016; Misati and Nyamongo, 2011). However, administrative issues and regulatory bottlenecks continue to stymie solar energy development in many developing countries (Kulichenko and Wirth, 2012).

The role of external actors is further complicated in Nigeria due to its entrenched fossil fuel interests and unstable regulatory environment. Counting politically linked oil and gas conglomerates, fossil fuel interest groups vehemently oppose strategies to advance

renewable energy, dreading potential revenue losses and reduced market control (Ebhota and Tabakov, 2018; Izoukumor, 2024; Oyewunmi and Ehanmo, 2021). This opposition creates barriers for solar energy investment from the external actors through lobbying, policy influence, and bureaucratic inertia (Aklin and Urpelainen, 2018). Different from some fossil fuel-rich developing countries such as Indonesia or Venezuela, where external actors have played leading role in policy shifts (Kingsbury, 2020; Maulidia et al., 2019), Nigeria's strong hydrocarbon reliance and vested interests demonstrate unique difficulties that complicate energy transition efforts (Okoh and Okpanachi, 2023; Olujobi et al., 2023). Bureaucratic inefficiencies and inconsistent government support have hampered large-scale solar projects in Nigeria, while external investors and development institutions have supported off-grid solar projects (Olujobi et al., 2023). The success of solar energy transition is largely affected by the interplay between financial incentives, institutional barriers, and geopolitical considerations.

Existing studies have highlighted the varying levels of influence exerted by different external actors in Nigeria's RE energy sector. Multinational corporations (MNCs) essentially engage through foreign direct investments (FDI) and technology transfer, but they frequently struggle with administrative insecurities and infrastructure obstacles (Aklin and Urpelainen, 2018). While MNCs provide large-scale capital and technological expertise, frail policy support and difficulties with exploring Nigeria's bureaucratic environment impede their ability to succeed (Ogunsola et al., 2024; Olujobi et al., 2023). Some scholars have also argued that MNC involvement is primarily profit-driven, with limited commitment to broader goals in energy access (Sesan et al., 2013).

There is literature indicating that international organizations (IOs) such as the World Bank and the African Development Bank, provide concessional financing and policy guidance, but problems such as institutional capacity constraints and policy inconsistencies cause them to face implementation challenges (Arezki and Sy, 2016). Some studies have also pointed out that while international organizations help shape regulatory frameworks and financial mechanisms, their involvement often struggle to have tangible results due to delays in government adoption and implementation inefficiencies (Bhattacharyya, 2013). Besides, the IOs-led solar initiatives may encounter conflicts with national policy priorities, creating coordination challenges (Blimpo et al., 2024).

Some scholars have illustrated that state-led investors, particularly those from China, are expanding through large-scale infrastructure projects and bilateral agreements, but questions about its long-term benefits have been raised due to concerns over debt sustainability and strategic interests (Chen et al., 2024). While China-led investment has facilitated rapid development of solar projects, some scholars have also argued that these initiatives often prioritize geopolitical and commercial interests over local capacity-building and sustainable development (Li et al., 2022). Other scholars have further indicated that the debates about accountability and governance risks have also been sparked resulting from the lack of transparency in state-led financing agreements (Newell, 2011; Pay and Nwosu, 2020; Roelofs, 2023).

Despite the contributions made by these external actors, there are significant gaps remained in understanding the different effectiveness of these external actors, particularly in exploring Nigeria's institutional complexities and fossil fuel dominance. There are some studies pointing out that external actor involvement may inadvertently strengthen existing power structures rather than disrupt them, halting the transition to renewable energy. While existing studies have examined the general role of external actor in RE transition, few studies have been done regarding how different types of external actor interact with domestic institutions and influence policy outcomes in Nigeria's solar sector. This highlights the need for a more in-depth analysis of external actor engagement, which will help this study's investigation focus on actor-specific effectiveness and contextual constraints.

2.2. Conceptualizing the Role of External Actors in Energy Transitions

This study applies the Multi-Level Perspective (MLP) to analyze the role of external actors in Nigeria's energy transition (Geels, 2002; Osunmuyiwa et al., 2018). The MLP model conceptualizes energy transitions between niche level, socio-technical regime level, and landscape level. This framework is particularly relevant to Nigeria, where external actors serve as agents introducing niche RE technology innovation that challenge the dominant fossil fuel regime.

External actors in the Nigerian context, including MNCs, IOs, and state-led investors, operate largely at the niche level, presenting new financial models, technologies, and policy frameworks (Aklin and Urpelainen, 2018; Chen et al., 2024; Sovacool, 2016). For instance, the World Bank's Scaling Solar initiative has provided concessional financing to support large-scale solar projects in sub-Saharan Africa, demonstrating the potential of international organizations to advance RE development (Lakai, 2020). Besides, China-led investments such as the Lekki solar farm project has illustrated how geopolitical strategies have impact on energy transitions, specifically by embedding renewable infrastructure within broader economic agreements (Alhassan, 2024). Moreover, MNCs such as TotalEnergies have entered Nigeria's solar market through distributed solar solutions for businesses, which displays a shift in corporate investment strategies toward sustainable RE (Newell et al., 2023). However, these advancements face strong opposition from the entrenched fossil fuel-based socio-technical regime, which is characterized by policy inertia, infrastructural limitations, and a vested economic interests (Gopalakrishnan and Miller, 2024). The integration of large-scale energy project is sometimes hampered by Nigeria's outdated and immature electricity grid infrastructure (Ebhota and Tabakov, 2018). In addition, powerful fossil fuel interest groups have been actively lobbing against policies promoting RE, dreading reduced market share, revenue losses and financial instabilities (Chinagorom et al., 2023). The dawdling implementation of Nigeria's Renewable Energy Master Plan has further demonstrated the institutional resistance to structural change, as bureaucratic inefficiencies and shifting policy priorities hinder the advance (Sovacool, 2021).

There are diverse global trends at the landscape level influencing Nigeria's transition dynamics, including climate change

commitments influence, declining RE innovation costs, and geopolitical shifts such as shifts in energy trade patterns, the diversification of oil importing-dependent economies, and the increasing impact of emerging markets in RE financing (Bridge and Gailing, 2020; Robb et al., 2024). While international pressures encourage RE adoption, domestic regime resistance hampers systemic change. Some scholars have indicated that the effectiveness of external actors in overcoming these challenges greatly depends on their capabilities to align niche innovations with broader structural transformations (Aklin and Urpelainen, 2018).

Though existing studies have extensively explored the role of external actors in RE development (Arezki and Sy, 2016; Bhattacharyya, 2013; Newell, 2011), few has done how these actors interact within fossil fuel-rich economies like Nigeria. These existing studies have predominantly examined policy frameworks (Sovacool, 2021), financial mechanisms (Arezki and Sy, 2016; Bhattacharyya, 2013), and infrastructure barriers (Bhattacharyya, 2013; Lakai, 2020), a comparative analysis of external actors' effectiveness in overcoming these challenges has remained largely unexplored. Given the expanding global push toward RE, understanding the factors that influence the effect of MNCs, IOs, and state-led investors in Nigeria is essential for both academic and policy discussions. This study aims to bridge this gap by using the Multi-Level Perspective (MLP) framework to analyze the interaction between niche, socio-technical regimes, and landscape levels in Nigeria's energy transition.

2.2.1. Research question

How do different types of external actors influence Nigeria's solar energy transition, and what factors shape their effectiveness?

2.2.2. Hypothesis

External actors influence Nigeria's solar energy transition through financial investments, policy advocacy, and capacity-building, but their effectiveness varies depending on actor type, alignment with domestic policies, and the resilience of fossil fuel interests. State-led investors may exert greater influence, but their impact remains moderated by governance and regulatory challenges.

3. METHODOLOGY

3.1. Research Design

This study employs a qualitative case analysis to examine the roles of various external actors in Nigeria's RE transition. There are three cases selected as solar energy projects led by three different external actors (IOs, MNCs, and state-led investors), which are respectively the Nigeria Electrification Project (NEP), the Ashama Solar Power Plant, and the Kaduna Solar Power Project. The comparative analytical approach enables a systematic assessment of how these different external actors shape project implementation, policy interactions, and overall effectiveness. The Multi-Level Perspective (MLP) framework is employed as the analytical lens to assess the interplay between niche innovation, institutional structures, and landscape pressures (Geels, 2002; Osunmuyiwa et al., 2018). This study will offer insights of how different external actors influence Nigeria's RE transition by applying this framework.

3.2. Case Selection

3.2.1. Justification of case selection

The NEP, Ashama, and Kaduna projects are selected based on their representativeness of distinct investments led by different external actors in Nigeria's solar energy sector. These cases allow for an in-depth analysis of how the effectiveness of different actors differs, factoring in conditions such as financial mechanisms, regulatory engagement, and scalability. In addition, these projects vary in their implementation scale and policy alignment, providing insights into the broader dynamics of Nigeria's solar energy investment.

3.2.2. Comparative case analysis framework

The Multi-Level Perspective (MLP) framework, which collaborates with investigations of the chosen project cases through three important analytical dimensions, is applied to structure the comparative case analysis.

3.2.2.1. Niche-level analysis

The analysis at this level examines each project's commitments to Nigeria's renewable energy transition, focusing on its technological configurations, implementation models, and potential for scalability. There are also some factors taken into account such as knowledge transfer, local capacity-building, and innovative business models that enhance project sustainability (Osunmuyiwa et al., 2018).

3.2.2.2. Socio technical regime-level analysis

This level evaluates the interdependence of each project with Nigeria's current institutional and regulatory frameworks. The degree of policy support, the impact of domestic fossil fuel interests, and alignment with energy policies are also examined at the level. Besides, it assesses how external actors explore administration challenges and regulatory barriers, forming the long-term feasibility of these investments (Sovacool, 2021).

3.2.2.3. Landscape-level analysis

This level examines the overall geopolitical, economic, and environmental drivers that comprise the selected projects' operational settings. Global climate finance trends, international political alignments (e.g., China's Belt and Road Initiative), and macroeconomic conditions affecting investment flows and energy transition policies are taken into consideration at this level (World Bank, 2021).

3.3. Data Collection

This study will utilize a multi-source data collection approach, incorporating both primary and secondary sources, to ensure the validity and reliability of the results. The primary data sources include government publications and official project documentation, which offers direct insight into regulatory frameworks and investment models. And the secondary data sources include academic literature, industry analyses, and energy transition databases, which provides broader contextual understanding. Details on project implementation challenges and policy interactions could also be provided from the above data sources (IRENA, 2023; World Bank, 2021). This approach increased the robustness of the findings and reduces potential biases from relying on a single data source type (Yin, 2017).

Supplementary sources include commercial filings from Siemens, Scatec, the Export-Import Bank of China, and reliable media reports such as The Guardian Nigeria, Premium Times, and Reuter. The expert opinions, which are derived from the policy brief and stakeholder interviews conducted by organizations like the World Bank and IRENA, encourage diversity in the analysis's interpretations of the effectiveness and barriers of external actors' involvement. By allowing for a thorough analysis of each program's financial, regulatory, and technological dimensions, the mixture of these diverse sources increases the robustness of this study.

3.4. Data Analysis

The comparative case analysis in this study takes a structured approach, integrating in-depth single case content analysis and cross-case analysis based on the MLP framework. The content analysis will be systematically codding textural data to identify repeating themes and patterns across policy documents, corporate reports, and expert opinions, which enables an in-depth examination of project investment effectiveness, policy alignment, and project sustainability (Bowen, 2009).

The cross-case analysis will facilitate the comparison of commonalities and differences among the selected three cases, which provides a nuanced understanding of how these external actors have impact on Nigeria's solar energy transition, and enables an assessment of key investment drivers, barriers, and outcomes across multiple analytical levels. Besides, the MLP-based evaluation of multiple data sources increases the validity and reliability of findings by cross-verifying evidence from different perspectives, which could contribute to a broader understanding of the role of various external actors in shaping RE transitions in fossil fuel-rich developing countries (Yin, 2017).

4. RESULTS

4.1. Niche-Level Analysis

Through the technological configurations, implementation models, and scalability potential, the three solar energy projects, NEP (IOs-led), Ashama (MNCs-led), and Kaduna (state-led), each make a significant contribution to Nigeria's transition to renewable energy. The international organizations-supported NEP emphasizes decentralized electrification through standalone systems and mini-grids, which focuses on rural access (Arezki and Sy, 2016). The multinational corporations-led Ashrama project uses large-scale solar farms and grid integration to increase renewable capacity in Nigeria (KPMG in Nigeria, 2021). The China-led Kaduna project prioritizes large-scale infrastructure with government-backed funding and technology transfer (IRENA, 2023).

Knowledge exchange and local community capacity-building levels vary significantly compared to the inspected circumstances. The NEP improves capability-building initiatives by implementing rural electrification programs and providing specialized training for local solar entrepreneurs, cultivating skilled labor in decentralized energy solutions (AfDB, 2024). Over 3,000 local specialists and entrepreneurs have been trained in the NEP's Solar Hybrid Mini-Grid system, extending their specialized technical knowledge in rural electrification (Otubu, 2021). By focusing on targeted programs and strategic collaborations with Nigerian engineering firms and strengthening technical expertise in large-scale solar installation, the Ashama project contributes to workforce advancement (Carabajal et al., 2024). Besides, it dedicates to establish partnerships with local academic institutions such as the University of Lagos, Ahmadu Bello University, and Covenant University. The solar energy-related courses are incorporated into engineering curricula in the local universities, and hands-on training is provided to over 500 students annually (KPMG in Nigeria, 2021).

Likewise, the China-led Kaduna project has also helped build local solar capacity through capitalizing on Chinese expertise to enhance skill development, leveraging technology transfer agreements and government-led training initiatives (Sambo, 2018), which has brought about more than 1200 trained local technicians and the specialized solar energy training centers, such as the China-Nigeria Renewable Energy Training Center and the Lagos Solar Energy Research Institute, in collaboration with Chinese institutions (IRENA, 2023). These activities have not only helped with improving skills rather than merely bolstering technical expertise but also established the long-term viability of Nigeria's renewable energy sector.

However, the viability of these endeavors depends ultimately on the effectiveness and adaptability of their business models, which determine their financial viability and resilience in the advancing energy landscape. NEP leverages a combination of public-private partnerships and benefactor subsidizing to boost decentralized electrification efforts, guaranteeing long-term financial sustainability and broader energy access (Federal Ministry of Power, 2024). In contrast to NEP, the Ashama project relies on market-driven mechanisms and private sector investments, illustrating a commercially viable approach to large-scale solar deployment. Impressively, Ashama project has secured more than 150 million dollars in private funding, promoting the installation of more than 200 MW of solar capacity (Federal Ministry of Power, 2024). Meanwhile, the Kaduna project is more financially stable and easier to develop large-scale infrastructure, benefiting from concessional financing and state-backed agreements. The Kaduna project's crucial partnership with China's Belt and Road Initiative has resulted in about 180 million dollars concessional loans, which strengthens its financial foundation and enables long-term operational practicality (IRENA, 2023).

The above similarities among these projects emphasize the importance of well-structured funding and coherent policy frameworks in expanding solar energy investments in Nigeria. All three cases particularly have demonstrated the importance of different external actors in promoting Nigeria's solar energy projects, which facilitate knowledge exchange, enhance financial accessibility and mitigate regulatory uncertainties, leading to more feasible and scalable solar energy development in Nigeria. The NEP has, for instance, secured more than 550 million dollars

in funding from institutions including the World Bank and the African Development Bank, to aid in improving over 200 mini-grid initiatives (Otubu, 2021). Similarly, the Ashama project has attracted over 150 million dollars international investments to finance the large-scale grid integration of renewable energy (KPMG in Nigeria, 2021). Likewise, the Kaduna project under China's Belt and Road Initiative receives about 180 million dollars in concessional financing, which strengthens its financial security and capacity (IRENA, 2023). From these figures, it can be seen that strategic funding and external partnerships are crucial in fostering the long-term sustainability and expansion of solar energy in Nigeria.

Nevertheless, remarkable differences have also been found regarding financial viability, scalability, and the extent to which these projects are incorporated within Nigeria's broader energy framework. While the NEP and the Ashama project are, to a great extent, driven by private sector investments and donor-led initiatives, the Kaduna Solar Power Project benefits from the state-backed investments and intergovernmental agreements (Edomah et al., 2021; A. Sharma, 2023; Ukponu et al., 2021; World Bank, 2023). This state-led approach sharply contrasts the NEP's more market-focused model, which centers heavily on mini-grid solutions and relies heavily on private sector involvement. NEP's success indeed can be attributed to its partnerships with private developers and the Rural Electrification Agency (REA, 2023). The Ashama project is also strongly based on private sector investment, particularly from well-known companies like B&S Power Holding and Sunnyfred Global. These companies have significantly contributed to the project expansion in combination with international organizations (Carabajal et al., 2024; KPMG in Nigeria, 2021) There are also differences from the perspective of project promotion models among three projects. In contrast to the market-focused projects such as NEP and Ashama, state-led Kaduna project heavily relies on comprehensive government collaboration to ensure stable and effective implementation (AfDB, 2024; Carabajal et al., 2024; KPMG in Nigeria, 2021; REA, 2023; RMI, 2020; A. Sharma, 2023).

The above models have highlighted the potential advantages of adopting a hybrid approach that combines all these models for ensuring long-term sustainability in Nigeria's energy transition (Edomah et al., 2021; Ukponu et al., 2021). It is also found that while private sector models-based MNCs-led and IOs-led initiatives have accelerated technological adoption, state-led investors have provided critical long-term stability compared to the former two type of external actors, which makes them a vital component for large-scale RE development in Nigeria (Edomah et al., 2021; Sharma, 2023; Ukponu et al., 2021; World Bank, 2023). The NEP, exemplification of rapid technological development fostered by the private sector models, has already performed well in facilitating over 250 mini-grids development, which enables more than 600,000 people in rural Nigeria with electricity access (Sharma, 2023; World Bank, 2023). But the state-led Kaduna project has performed even better in providing electricity to over 1.2 million people (AfDB, 2024), which highlights the relative advantage of state-led investments in large-scale projects in Nigeria.

4.2. Socio-technical Regime-Level Comparative Analysis

Significant differences in policy support and challenges are found in how these projects interact with Nigeria's institutional and regulatory systems. The Nigeria Electrification Project (NEP), for example, adapts to Nigeria's off-grid electrification policies, which benefits from the Mini-Grid Regulation (NERC, 2015a). Under these policies, NEP has promoted mini-grid development and encourages private sector involvement. Nevertheless, the rooted fossil fuel interest groups present a considerable obstacle, as subsidies for diesel and kerosene continue to weaken the competitiveness of solar energy solutions, as highlighted by Emodi and Boo (2015). By contrast, the Ashama project has encountered critical regulatory challenges including complications with power purchase agreements (PPAs) and bureaucratic delays, which impede timely project execution (Emodi and Boo, 2015), despite being supported by favorable policies such as the National Renewable Energy and Energy Efficiency Policy (NREEEP) (NERC, 2015b). Meanwhile, the China-backed Kaduna Solar Power Project has experienced regulatory inconsistencies and local content prerequisites, leading difficulty in its implementation process. These obstacles are made worse by the challenges posed by Nigeria's changing regulatory environment (IEA, 2022).

Therefore, it becomes clear that a practical policy enforcement is crucial to removing these obstacles and ensuring the viability and success of solar energy investments. Nigeria's Electrification Project (NEP) benefits from significant international support, giving Nigerian regulatory agencies more weight to streamline processes and reduce bureaucratic inefficiencies. Through mechanisms promoting private sector involvement in off-grid solutions, such as Rural Electrification Fund, this international support has made it easier to smoother project implementation (Sharma, 2023; World Bank, 2023). By contrast, the Ashama project has suffered in effective implementation of supportive policies, due to fragmented regulatory oversight. This finding highlights that it is necessary to have more predictable and cohesive policy enforcement to ensure project sustainability (Sambo, 2018).

Compared to NEP and Ashama project, the Kaduna project has possessed relative policy stability, largely benefiting from high-level government agreements between Nigeria and China, encouraging a favorable regulatory environment for large-scale investment (AfDB, 2024). However, despite this relative stability the Kaduna project has experienced, it still has undergone resistance from rooted fossil fuel interest groups and local labor unions, who are concerned about the potential dominance of foreign workforce participation in the project's execution (IRENA, 2023). This finding highlights that even with stable policy enforcement, there are still difficulties in balancing foreign investment with local stakeholder interests in Nigeria's energy transition.

The cross-case analysis at the socio-technical regime level has provided significant insights into the role of different external actors in Nigeria's solar energy transition, particularly when considering the entrenched dominance of fossil fuel interests (Adeniyi, 2019; Nweke-Eze, 2022). There are critical disparities

in policy support and institutional challenges in Nigeria's RE transition. From the cross-case comparison, it can be seen that state-led investors with more robust governmental backing have performed better in facing the complexities of entrenched fossil fuel interests in Nigeria, rather than international organizations and multinational corporations in spite of their contribution in bringing innovative business models to Nigeria. (Adeniyi, 2019; Ukponu et al., 2021). External state-led investment's advantage lies in the direct government involvement in policy formulation, regulatory alignment, and strategic financial support, which all contribute to smoother project implementation (Adedokun, 2024; AfDB, 2024). Chinese government's engagement in the Kaduna project guarantees long-term commitment through intergovernmental agreements, whereas multinational corporations-led investment like Ashama project frequently experience delays caused by prolonged negotiations over power purchase agreements (PPAs) and regulatory approvals (IEA, 2022; IRENA, 2023; Sambo, 2018). External state-led project's another advantage is that it frequently benefits from preferential access to concessional financing, which lessens financial barriers and mitigates related risks (AfDB, 2024; Edomah et al., 2021; Sharma, 2023; Ukponu et al., 2021). This finding highlights the need for external actors to make sure their investment alignment with local policy frameworks and governance structures (Edomah et al., 2021; Ukponu et al., 2021).

4.3. Landscape-Level Analysis

How projects led by different external actors have impact on Nigeria's solar energy transition is significantly influenced by broader geopolitical, economic, and environmental dynamics. For instance, NEP and Ashama project have been provided critical financial support to enhance their implementation from international climate finance mechanism such as those under the Paris Agreement (AfDB, 2024; UNFCC, 2015). Kaduna project has been benefited from China's Belt and Road Initiative (BRI), which underscores China's strategic investment in African energy markets and its broader geopolitical interest in Africa (IEA, 2022; Jing et al., 2020; Shen, 2020). However, all three projects could be exposed to significant macroeconomic challenges such as foreign exchange volatility, inflation, and fluctuating commodity prices, thus impacting investment flows and financial sustainability. This finding emphasizes the importance of stable economic environments for ensuring the viability and long-term success of renewable energy projects (Nwanevu et al., 2024; Otubu, 2021).

In facing these global challenges and opportunities, the Nigerian government's commitment to relieving carbon emissions could play a prominent part in integrating solar energy solutions into the country's national energy mix. The Ashrama project contributes to the expansion of large-scale, grid-connected solar power in Nigeria, while the NEP specifically aligns with Nigeria's off-grid electrification targets, which point to providing energy access to underserved populations (IRENA, 2023). Despite being a primarily government-led initiative, the Kaduna project must manage Nigeria's complex dual dependence on fossil fuels and the transition to renewable energy (Emodi and Boo, 2015). It is worth noting that the enhanced access to climate financing has been facilitated in NEP and Ashama project through leveraging multinational corporations' investments and receiving aids form international organizations. The Kaduna project, on the other hand, largely depends on bilateral agreements and concessional loans, which has shown how dependent it is on state-backed financial tools to overcome financial constraints and secure project viability (AfDB, 2024).

These findings highlight the fundamental role that external actors play in shaping the distribution of solar power, particularly in fossil fuel-rich nations like Nigeria. Despite the increasing investment in solar energy projects brought by global climate finance trends, challenges like rooted fossil fuel industries and macroeconomic precariousness continue to present significant obstacles (IRENA, 2023; Otubu, 2021). The success of external state-led investments are particularly exemplification within this context, which highlights that strong government alignment and strategic intergovernmental cooperation could provide a more steady and conducive environment for encouraging long-term energy transitions in Nigeria (AfDB, 2024; IEA, 2022). This finding further supports the claim that state-led investments are more financially positioned to explore resistance from fossil fuel interests and support the development of renewable energy, particularly in fossil fuel-exporting nations with built-up fossil fuel segments (Emodi and Boo, 2015).

5. DISCUSSION

In this study, how three types of external actors impact on Nigerian's solar energy transition are differed has been investigated. The three types of external actors are international organizations, multinational corporations, and state-led investors (specifically China), whose leading projects are respectively NEP, Ashama project, and Kaduna project. The results demonstrate that Chinese government-led Kaduna project has shown better performance in enhancing large-scale solar deployment, which benefits from strong policy alignment and concessional financing that provide greater project stability. The MNCs-led Ashama project, who also focus on large-scale solar deployment, however, has not been executed as smoothly as the Kaduna project. But both MNCs-led Ashama project and IOs-led NEP have contributed to technological innovation and market expansion in spite of regulatory and financial challenges. These findings suggest that while all three investment models play a role in Nigeria's energy transition, state-backed projects may be better suited to overcoming systemic barriers and ensuring long-term project sustainability (IRENA, 2023; Otubu, 2021).

The study's findings align with those of earlier studies on fossil fuel-dominated countries' renewable energy investments. Earlier studies have shown that international organizations-driven initiatives like NEP promote energy access but are constrained by concerns about long-term financial sustainability (AfDB, 2024; Otubu, 2021). The role of multinational corporations in scaling up renewable projects has also been studied, highlighting challenges related to regulatory uncertainty, power purchase agreements (PPAs), and the complex interaction between local policies and global corporate strategies (Osunmuyiwa et al., 2018; Sambo, 2018). The Kaduna project has exhibited stability,

which is consistent with existing studies on China's Belt and Road Initiative (BRI). This highlights the effectiveness of state-led investments in infrastructure development through concessional financing, government-to-government agreements, and strategic geopolitical interests (IEA, 2022; Jing et al., 2020; Shen, 2020; Zeng et al., 2022). These findings suggest that a cross-sector strategy that incorporates the benefits of different investment models may most effectively maintain a diverse and sustainable energy transition in Nigeria.

There is an unexpected finding from this study, which is the degree to which geopolitical factors affect the success of state-led investments. The success of the Chinese government-led Kaduna project may be more directly related to strategic diplomatic consideration than to than the inherent advantages of state-led investment models, despite earlier studies acknowledging China's role in Africa's energy sector. This insight aligns with broader studies on China's foreign policy, which underscore how geopolitical relationships, including the Belt and Road Initiative (BRI), significantly shape energy investments, particularly in fossil fuel-rich regions (IEA, 2022; Jing et al., 2020; Shen, 2020; Zeng et al., 2022). Additionally, the study discovered that the fossil fuel market's regulatory inefficiencies and contradictions have disproportionately impacted private sector investments, which is a problem that hasn't been addressed in the existing literature. The regulatory inefficiencies will make market entry harder and impede the competitiveness of RE solutions, which could have significant impact on long-term financial sustainability (Osunmuyiwa et al., 2018; Sambo, 2018). These findings have highlighted that considering both geopolitical factors and regulatory challenges in evaluation of investment models and their potentials is of great importance in supporting RE transition in developing economies, particularly those who are fossil fuel abundant.

Nevertheless, there are also some limitations need to be considered. Given Nigeria's broader scope of renewable energy investments, this study only examined three representative solar energy projects. Although these projects offer valuable insights, the selection may not fully account for the diversity of investment models across various industries, sectors, and project sizes, affecting the findings ' general applicability (Sambo, 2018). Additionally, the limited availability of project-specific data, particularly regarding economic arrangements, operating performance, and long-term sustainability metrics, may impact the depth and breadth of the analysis (Bolarinwa and Akinbobola, 2021). Moreover, the study heavily relied on the Multi-Level Perspective (MLP) framework, which does not fully account for the micro-level dynamics, such as community engagement, socio-economic impacts, and the role of local innovation in driving renewable energy adoption (Geels, 2002; Osunmuyiwa et al., 2018). This limitation suggests that future studies could consider both top-down and bottom-up perspectives to better understand the complexity of the energy transition at nearby levels. Besides, although the MLP framework offers useful insights into systemic transitions, it struggles to address the political and institutional challenges in RE project that fossil fuel-rich countries face, which aligns with the existing studies (Aghion et al., 2019). Therefore, future research could overcome these limitations by incorporating more case research and mixed-method approaches.

Based on the findings of this study, future studies could look at the long-term performance of state-led renewable energy efforts to determine whether their initial stability leads to continuous effects. Specifically, studies in the future could examine the continual effects of authorities-backed initiatives on energy access, economic development, and environmental outcomes, since earlier studies have already highlighted the importance of long-term financial sustainability in such projects (AfDB, 2024; Akinyele et al., 2020). Furthermore, comparative studies between Nigeria and other fossil fuel-rich developing economies, such as South Africa or Indonesia, could yield valuable insights into the role of external actors in shaping energy transitions, particularly in contexts where fossil fuel industries hold considerable political and economic power (Edomah et al., 2021; IEA, 2022). Additionally, research into hybrid investment models that incorporate private sector stability and private sector efficiency could provide significant lessons for scaling renewable energy initiatives in economies sharing similar geopolitical and economic settings (Geels, 2002; Sambo, 2018). Finally, studying the political-economic impacts of renewable energy projects, particularly concerning local job creation, energy affordability, and community empowerment, could provide a more integrated understanding of their effectiveness and broader advantages, as these factors are essential for maintaining the social legitimacy of such initiatives (Lackner and Sachs, 2005). Research in this direction may enable a complete evaluation of solar energy's role in addressing development problems in fossil fuel-rich countries.

This study underscores the strengths and limitations of various investment models in Nigeria's solar energy transition, concealing that while state-led investments provide stability, multinational corporation-led and international organizations-led initiatives promote innovation and market expansion. The findings in this study have highlighted that it is necessary to effectively combine the advantages of each model to grasp Nigeria's sophisticated energy landscape, which provides broader implications for policymaker and investors who aim to promote renewable energy development, especially in fossil fuel-rich countries. In this context, strengthening institutional frameworks, ensuring policy coherence, and growing strategic partnerships with governments, corporations, and international development agencies are essential to expanding renewable energy initiatives in Nigeria and providing long-term energy sustainability.

6. CONCLUSION

The shift to renewable energy, particularly in Nigeria's geologically fossil fuel-focused countries, is a pressing global issue. The study examined three different external actors' investment models in Nigeria's solar energy sector using the Multi-Level Perspective (MLP) framework, which are state-led, multinational corporation-led, and international organization-led. Despite each type of solar project's contribution to renewable energy development, state-led projects have exhibited a stronger regulatory framework and a longer-term commitment, which strengthen their position as a

strong force in eliminating policy and financial barriers. Besides, international organization-led and multinational corporation-led projects have shown their great importance in expanding market participation and developing technological innovation.

Despite these insights gained in this study, there are also some limitations that need to be taken considerations. The case selection of only three solar energy projects in this study may not comprehensively capture the diversity of Nigeria's renewable energy investments. Additionally, the study primarily relied on publicly available information, which limited exposure to internal project evaluations and financial details. Furthermore, the MLP framework in this study fails to fully account for local socio-economic factors such as community engagement and social acceptance of renewable energy, despite it provides useful analysis structure.

Possible future research could uncover hybrid investment models that combine the strengths of state-led, international organization-led, and multinational corporation-led initiatives. It is essential to apply some longitudinal studies on examining the long-term performance and sustainability of these project. Besides, future research could also focus on comparing Nigeria and other fossil fuel-rich countries, which could provide deeper insights into the role of external actors in shaping renewable energy transition in such fossil fuel abundant economies.

This study has significance in providing valuable lessons for other fossil fuel-rich developing countries who are looking to increase their renewable energy development, not just limited to Nigeria context alone. Drawing from this study, there are several things crucial for scaling renewable energy development in fossil fuel-rich economies, which are strengthening institutional frameworks, ensuring policy consistency, and fostering strategic partnerships between governments, multinational corporations, and international development agencies. Through these approaches, it will greatly help the fossil fuel abundant countries with creating more resilient and sustainable energy system that could strike a balance between innovation and regulatory stability, helping to advance global efforts toward a low-carbon possible.

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