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Integrated Waste-to-Energy Policy Model for Urban Sustainability in West Africa

Mohammed Lawal Giwah [1*], Zamathula Sikhakhane Nwokediegwu [2], Emmanuel Augustine Etukudoh [3], Ebimor Yinka Gbabo [4]

[1] Kwara State Government - Ilorin, Nigeria
[2] Independent Researcher, Durban, South Africa
[3] Independent Researcher, Nigeria
[4] Nuclear Security Technologies (UK), UK

* Corresponding Author: **Mohammed Lawal Giwah**

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Abstract
The global shift toward renewable energy is an urgent response to escalating climate threats, energy insecurity, and the need for inclusive economic development. However, in many regions, especially in emerging economies, the pace of renewable energy adoption remains constrained by regulatory inefficiencies, financing bottlenecks, and infrastructural limitations. This paper explores how public-private policy instruments can be effectively designed and deployed to overcome these barriers and catalyze large-scale renewable energy adoption. It presents a comprehensive analysis of public policy tools, regulatory, market-based, and informational, and examines how their integration within public-private partnerships can drive investment, innovation, and long-term sustainability. Drawing from public governance theories, innovation diffusion models, and transition frameworks, the paper emphasizes the strategic value of hybrid governance structures. It identifies key design components, including de-risking mechanisms, green finance models, and inter-agency coordination strategies, that enhance the effectiveness of collaborative energy governance. The study further outlines institutional and technical challenges, from grid readiness to investment risk, and proposes adaptive, inclusive solutions grounded in systems thinking and co-governance. By synthesizing theoretical insights and practical policy approaches, the paper contributes to a growing body of knowledge on energy transition governance. It concludes with strategic recommendations for policymakers, investors, and development actors to institutionalize public-private cooperation, strengthen market confidence, and accelerate the transition to a low-carbon, energy-secure future.

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1. Introduction

1.1 The Imperative for Renewable Energy Transition

The global energy landscape is undergoing a profound transformation driven by the urgent need to shift away from fossil fuels toward cleaner, more sustainable energy sources. This transition is fueled by the converging crises of climate change, environmental degradation, and resource depletion [1, 2]. Fossil fuel dependence has led to rising greenhouse gas emissions, extreme weather events, and significant ecological disruptions. These challenges demand comprehensive policy responses and long-term structural reforms that prioritize renewable energy as a cornerstone of climate resilience and environmental sustainability [3, 4]. In many developing and emerging regions, including sub-Saharan Africa, Southeast Asia, and parts of Latin America, energy poverty remains a critical obstacle to development.

A large proportion of the population lacks access to reliable, affordable electricity [5]. Renewable energy offers a practical solution to bridge this access gap while avoiding the carbon-intensive pathways followed by industrialized economies. Technologies such as solar photovoltaics, wind power, and bioenergy are increasingly viable, scalable, and adaptable to decentralized applications, particularly in rural and peri-urban areas [6].

Beyond environmental and developmental concerns, renewable energy also enhances energy security by reducing dependence on volatile fossil fuel imports and promoting domestic resource utilization. This has become particularly relevant amid geopolitical tensions and global supply chain disruptions. For many countries, diversifying energy sources through renewables represents not just an environmental imperative but also a strategic necessity for economic stability and national sovereignty. These multifaceted benefits underscore why a deliberate policy shift toward renewable energy is essential [7, 8].

1.2 Role of Public-Private Collaboration

Public-private collaboration in the energy sector refers to structured partnerships between government entities and private actors to co-design, finance, implement, and regulate energy infrastructure and services [9]. These collaborations can take many forms, including public-private partnerships (PPPs), co-financing arrangements, policy incentive schemes, and regulatory co-production. At their core, they aim to leverage the strengths of each sector: the public sector's authority, planning capacity, and social mandate, as well as the private sector's efficiency, innovation, and financial resources [10].

The role of public-private instruments in renewable energy development has gained prominence as governments face fiscal constraints and increasing demand for clean energy infrastructure. Hybrid governance models provide a practical solution to resource gaps while enhancing policy flexibility and responsiveness [11]. Through well-designed instruments such as feed-in tariffs, tax incentives, green bonds, and risk-sharing frameworks, governments can de-risk investments and create attractive conditions for private sector entry into the renewable energy market [12, 13].

Moreover, collaborative policy frameworks encourage innovation by fostering competitive markets and incentivizing research, development, and deployment of new technologies. Joint ventures and innovation hubs often emerge from these synergies, allowing for faster scaling of renewable energy solutions. These models also enhance accountability and transparency, particularly when clear performance indicators, contractual obligations, and regulatory oversight are in place. As such, public-private collaboration is not merely complementary to state-led energy planning, it is increasingly indispensable for achieving wide-scale renewable energy adoption [14, 15].

1.3 Research Purpose and Relevance

This study seeks to explore and evaluate how public-private policy instruments can be optimized to accelerate the adoption of renewable energy technologies. The objective is to analyze the structural, financial, and institutional dynamics of these instruments and identify best practices that can enhance their effectiveness in varied contexts. In doing so, the paper aims to develop a strategic framework that aligns the interests of public and private stakeholders while addressing systemic barriers to clean energy deployment.

The relevance of this research lies in its potential to contribute to both policy and practice. In the context of rising energy demand, constrained public budgets, and pressing climate targets, traditional top-down models are proving insufficient. There is a growing need for more agile, inclusive, and innovation-oriented policy tools that can catalyze investment and deliver reliable, scalable, renewable energy solutions. Public-private instruments offer a pathway to achieve this, but their design and implementation require careful calibration to local political, economic, and regulatory conditions.

Importantly, this research aligns with global sustainable development and climate goals, including the UN Sustainable Development Goal 7 (affordable and clean energy) and the Paris Agreement. By examining the intersection of policy design, market dynamics, and institutional collaboration, the paper aims to inform national energy strategies and multilateral efforts focused on green transitions. It also contributes to broader debates on governance innovation, energy justice, and sustainable development, making its insights valuable for decision-makers, investors, and scholars alike.

2. Theoretical and Policy Foundations

2.1 Public Policy Instruments for Energy Governance

Public policy instruments are the tools through which governments influence behavior, allocate resources, and guide socio-economic transformation. In the context of energy governance, these instruments are commonly categorized into three broad types: regulatory, market-based, and informational. Regulatory instruments include mandates, licensing rules, and environmental standards such as emissions caps or renewable energy quotas [16, 17]. Market-based tools rely on economic incentives, such as subsidies, feed-in tariffs, carbon pricing, and tax incentives. Informational instruments aim to shape behavior through awareness campaigns, labeling schemes, and technical assistance programs [18, 19].

The selection and design of these instruments are deeply rooted in public policy theory, particularly in frameworks that address instrument choice, policy effectiveness, and governance capacity. Theories of policy instrument choice emphasize context sensitivity, institutional feasibility, and target group behavior. Instruments must align with existing administrative structures, socio-political dynamics, and market conditions. A poorly designed tool may fail despite strong political intent if it lacks implementability or fails to generate stakeholder buy-in [20, 21].

In energy governance, policy instruments must also reflect the complexity of technological transitions and long investment horizons. Effectiveness is not solely determined by design but also by the coherence of the instrument mix and the robustness of implementation. A strategic blend of policy tools, tailored to national goals and reinforced through iterative evaluation, can create the enabling conditions necessary to accelerate renewable energy deployment while safeguarding equity, environmental integrity, and long-term efficiency [22].

2.2 Public-Private Partnerships and Co-Governance Models

Public-private partnerships (PPPs) and co-governance models represent evolving frameworks that blend state

authority with private sector efficiency to address infrastructure and service delivery needs, especially in complex sectors like energy. PPPs involve long-term contractual arrangements where private entities invest in, build, and often operate infrastructure in exchange for government-backed payments or shared revenues. These arrangements are governed by detailed performance benchmarks and legal agreements designed to allocate risks and responsibilities [23].

The success of public-private collaboration hinges on strong institutional frameworks that provide transparency, legal certainty, and regulatory stability. Governments must create enabling environments by streamlining approval processes, establishing fair dispute resolution mechanisms, and ensuring policy consistency. At the same time, private partners must commit to accountability and performance delivery, particularly when projects involve public goods such as electricity or environmental sustainability. Co-governance models take this further by integrating shared decision-making, emphasizing stakeholder participation, and fostering joint responsibility in policy formulation and monitoring [24, 25]. Trust and risk-sharing are central to these arrangements. In renewable energy, where technology risks, market fluctuations, and long payback periods can deter private investment, effective co-governance provides a stabilizing mechanism. Instruments such as viability gap funding, sovereign guarantees, and performance-based subsidies can redistribute risk in ways that attract capital while ensuring public interest outcomes. Furthermore, collaborative governance models encourage innovation, unlock synergies, and enhance legitimacy by building a culture of mutual accountability between the state, businesses, and civil society [26, 27].

2.3 Innovation Diffusion and Transition Theory

Understanding the adoption of renewable energy technologies requires a theoretical foundation rooted in innovation diffusion and transition theory. Innovation diffusion theory, developed by Everett Rogers, explains how new technologies spread across populations over time, influenced by factors such as relative advantage, compatibility, complexity, trialability, and observability. In the context of renewable energy, these factors determine whether new systems, such as solar panels, wind turbines, or battery storage, are perceived as beneficial, usable, and economically viable by individuals, firms, and governments [28].

Transition theory builds upon this by exploring how large-scale socio-technical systems evolve. It focuses on the interactions between niche innovations, established regimes, and broader landscape pressures. In renewable energy, niche innovations often struggle to scale due to resistance from entrenched fossil fuel systems, infrastructural inertia, and institutional path dependency. However, strategic policy interventions, such as subsidies for early adopters, investments in pilot projects, and regulatory mandates, can help create protective spaces for innovation to flourish and eventually challenge dominant paradigms [29].

Policy instruments that support innovation diffusion must be adaptive and targeted across different stages of technology development, from R&D to commercialization and mass deployment. These include demonstration grants, net metering policies, green procurement, and technical training programs. Over time, as adoption increases and cost curves decline, market forces become more favorable, and public-private collaboration plays a crucial role in mainstreaming innovation. The interplay of theory and policy practice in this space is essential to understanding how societies can transition toward a low-carbon energy future [30, 31].

3. Barriers to Renewable Energy Adoption

3.1 Regulatory and Institutional Gaps

One of the most persistent barriers to renewable energy deployment is the presence of regulatory and institutional gaps. Policy fragmentation is common, where overlapping laws and misaligned strategies across different government agencies create confusion and inefficiency. For instance, energy ministries may push renewable targets while finance or environmental authorities impose contradictory requirements, leading to miscoordination. Bureaucratic delays in obtaining permits, land access, or environmental clearances further discourage investment and slow project implementation [32].

Licensing procedures for renewable energy projects often involve multiple institutions and unclear timelines, adding to investor uncertainty. These administrative inefficiencies can delay project execution by months or even years, increasing development costs. Moreover, in many developing and emerging economies, weak institutional enforcement undermines the effectiveness of policy incentives or mandates. Feed-in tariffs, renewable portfolio standards, or net metering frameworks may be legislated but poorly implemented due to a lack of monitoring or political will [33, 34].

Compounding this is the issue of overlapping mandates and institutional turf battles. When multiple agencies claim responsibility for energy policy, regulatory bottlenecks proliferate and accountability becomes diluted. This fragmentation erodes investor confidence, distorts planning, and prevents a cohesive national energy vision. Addressing these gaps requires governance reform, streamlined procedures, inter-agency coordination mechanisms, and stronger legal enforcement tools that collectively improve the policy environment for renewables [35, 36].

3.2 Financial Constraints and Market Risks

Renewable energy technologies, while increasingly cost-competitive, still demand significant upfront investment that deters adoption, particularly in capital-constrained economies. Solar farms, wind turbines, grid infrastructure, and battery systems involve high fixed costs, which are difficult to recover without reliable long-term revenue streams. Many developers, especially smaller enterprises, struggle to access affordable financing due to limited credit histories, underdeveloped capital markets, or the absence of tailored financial instruments [37, 38].

Investors often perceive renewable energy as high-risk due to several interlinked factors: long payback periods, technological uncertainties, currency volatility, and inconsistent regulatory environments. These risks inflate the cost of capital or lead to project rejection altogether. In countries with a history of sudden policy reversals, such as the removal of subsidies or delays in feed-in tariff payments, confidence in long-term profitability erodes, further compounding financing difficulties [39].

Moreover, financial institutions may lack the expertise to appraise renewable projects or remain hesitant due to unfamiliar business models like distributed generation or off-

grid systems. The absence of de-risking instruments such as guarantees, insurance, or blended finance structures means that investors often pass on potentially viable projects. Without robust policy signals and financial de-risking frameworks, the market for renewable energy will remain undercapitalized, limiting the pace and scale of the energy transition [40, 41].

3.3 Infrastructure and Technical Limitations

The adoption of renewable energy is also hindered by structural infrastructure limitations and technical challenges. Many electricity grids, particularly in developing countries, are outdated, overloaded, or poorly maintained, limiting their capacity to integrate variable renewable sources such as wind and solar. Weak grid infrastructure often results in transmission losses, congestion, and grid instability, which are exacerbated when intermittent renewable sources are added without adequate balancing or storage systems.

Storage technology remains a key bottleneck. Without cost-effective and scalable energy storage solutions, integrating high shares of renewables is technically difficult. The intermittency of solar and wind power requires either flexible backup generation or sophisticated demand-response systems, both of which are often lacking. The absence of smart grids, real-time monitoring, and grid automation further reduces the operational flexibility needed to accommodate renewable inputs efficiently [42].

Beyond infrastructure, there is a critical shortage of skilled technical personnel in areas such as project design, installation, maintenance, and system integration. Many countries also lack domestic manufacturing capacity for renewable components, resulting in heavy reliance on imports, which increases costs and limits supply chain resilience. Addressing these technical barriers will require large-scale investments in grid modernization, storage technologies, workforce training, and regional manufacturing hubs. Without resolving these issues, renewable energy adoption will struggle to achieve meaningful scale and reliability [43, 44].

4. Designing Effective Public-Private Policy Instruments

4.1 Regulatory Frameworks and Incentive Structures

Effective regulatory frameworks form the backbone of public-private engagement in renewable energy development. Instruments such as feed-in tariffs (FiTs) offer long-term price guarantees for electricity generated from renewable sources, thereby reducing revenue uncertainty and making projects more bankable. Renewable portfolio standards mandate that utilities source a specific percentage of electricity from renewables, create market demand, and stimulate private sector investment. Streamlined permitting and licensing procedures are equally critical, as they lower transaction costs and reduce bureaucratic bottlenecks [42, 45].

Beyond baseline regulations, governments must implement de-risking mechanisms that shield private investors from policy, market, and technical uncertainties. Investment guarantees, such as those provided through public credit agencies or sovereign backstops, can mitigate risks related to payment defaults, currency fluctuations, or regulatory changes. Similarly, insurance instruments for political and technical risks enhance investor confidence in emerging markets, where policy volatility or grid unreliability may otherwise deter capital inflows [46].

The success of these frameworks depends not just on their design, but also on consistent enforcement and credibility. Regulatory clarity and long-term policy stability signal to private actors that governments are committed to the renewable energy transition. When aligned with performance metrics and periodic reviews, these frameworks can incentivize efficiency, innovation, and competition while ensuring public accountability and environmental integrity in the energy sector.

4.2 Financing Mechanisms and Investment Models

Financial innovation is critical to scaling renewable energy deployment, especially in environments with high capital costs and limited access to conventional financing. Green bonds are one such instrument that has gained traction globally. These fixed-income securities are earmarked for climate and environmental projects, offering investors both returns and sustainability credentials. By enabling institutional investors to channel funds into renewable energy, green bonds expand the pool of long-term, low-cost capital [47, 48].

Blended finance models further enhance financial viability by combining concessional public funding with commercial capital. This structure allows public funds to take on the initial risk, making projects more attractive to private investors. Concessional loans, grants, or first-loss tranches can improve financial returns and enable marginal projects to reach bankability. Such models are particularly effective in rural electrification and distributed renewable systems where returns are uncertain or slow [49].

Multilateral institutions, such as the World Bank, African Development Bank, and regional development funds, play an essential role in facilitating these investment models. They offer technical assistance, guarantees, and co-financing platforms that mobilize private capital at scale [50]. Sovereign guarantees provided through national governments or backed by multilateral agencies ensure contractual enforcement and reduce the risk of payment default. Together, these instruments expand the financing frontier, allowing diverse actors to co-invest in sustainable energy systems [51].

4.3 Institutional Coordination and Capacity Building

The effectiveness of public-private policy instruments is contingent on strong institutional coordination across different levels of government and sectors. Fragmented governance structures can lead to policy inconsistencies, duplication of efforts, and competition over mandates. Establishing inter-agency coordination mechanisms, such as joint planning committees, national energy councils, or one-stop regulatory platforms, ensures policy coherence and harmonized implementation. Vertical coordination between national, regional, and local authorities is also critical to align strategic planning with on-the-ground realities [52].

Capacity building must accompany coordination efforts to bridge institutional gaps and enhance implementation capability. Public officials require training in renewable energy finance, procurement, and contract management to engage with private partners effectively. Similarly, regulatory bodies must be equipped to evaluate complex technical proposals, enforce compliance, and resolve disputes. Investing in institutional learning and human capital development strengthens the overall governance ecosystem necessary for scaling renewable energy projects [53, 54].

Stakeholder platforms that include government agencies, private firms, civil society, and academia are vital for

fostering dialogue, transparency, and shared ownership of energy policies. These platforms promote knowledge exchange, surface local insights, and help ensure that policy design is inclusive and context-sensitive. By embedding learning, participation, and adaptive capacity into institutional processes, governments can create an enabling environment where public-private collaboration thrives and renewable energy adoption is sustained [55].

5. Conclusion and Recommendations

5.1 Summary of Key Contributions

This paper has examined the critical barriers and enabling mechanisms for renewable energy adoption through the lens of public-private policy instruments. It highlighted how regulatory fragmentation, financial constraints, and infrastructural limitations continue to obstruct progress in many regions, particularly in emerging markets. Simultaneously, it demonstrated how targeted policy tools, such as feed-in tariffs, de-risking instruments, and blended finance, can incentivize private sector participation and accelerate energy transitions when embedded in robust institutional frameworks.

The analysis drew upon key theoretical models, including public policy instrument typologies, innovation diffusion, and co-governance approaches, to frame renewable energy as both a technical and institutional challenge. Public-private partnerships were identified not merely as funding mechanisms but as strategic platforms for shared innovation, risk mitigation, and governance reform. These frameworks help overcome the limitations of siloed policymaking and create adaptive, multi-stakeholder environments essential for transformative change.

In synthesizing the core themes, the paper contributes to an evolving understanding of energy governance by underscoring the importance of instrument design, institutional alignment, and long-term collaboration. Public-private instruments are not stand-alone solutions, but elements of a broader strategy that links policy intent with implementation capacity. By combining theoretical rigor with policy relevance, this research offers actionable insights for stakeholders seeking to unlock the full potential of renewable energy systems.

5.2 Strategic Implications for Renewable Energy Transitions

The strategic implications of adopting integrated public-private policy approaches are profound. First, these models enhance energy security by diversifying energy sources and reducing reliance on imported fossil fuels. With increasing geopolitical volatility and climate-related risks, countries can use renewables to stabilize their domestic energy supply and protect themselves from global energy price shocks. This contributes to national resilience and long-term development planning.

Second, public-private instruments are pivotal in meeting decarbonization targets. By incentivizing cleaner technologies and accelerating innovation cycles, these tools enable countries to align with international climate goals, such as those outlined in the Paris Agreement. Institutionalized collaboration allows for flexible policy evolution, which is critical in navigating the uncertainties of technological change and shifting market dynamics. It also facilitates investment in complementary systems, such as smart grids and storage, which are vital for deep decarbonization.

Third, such collaboration strengthens innovation capacity by pooling resources, knowledge, and risk. Private firms bring technical expertise and agility, while the public sector ensures regulatory stability and social equity. The result is a more inclusive and responsive energy ecosystem, capable of adapting to local contexts while achieving global ambitions. These strategic advantages affirm that the long-term value of institutionalized public-private cooperation extends beyond energy, it reinforces governance, accelerates sustainable development, and enhances national competitiveness.

5.3 Recommendations for Policymakers and Stakeholders

Several key recommendations emerge to optimize renewable energy adoption through public-private instruments. First, governments must strengthen regulatory clarity by harmonizing existing laws, streamlining licensing procedures, and eliminating contradictory mandates. Regulatory stability is essential for investor confidence and long-term project planning. Establishing independent energy regulators and transparent monitoring systems will further enhance credibility and reduce political risk.

Second, stakeholders should prioritize inclusive partnerships that engage not only government agencies and private developers but also civil society organizations, local communities, and academia. These collaborations ensure that policies are grounded in lived realities and social equity is not sacrificed for technical or financial efficiency. Inclusive decision-making also builds trust, improves uptake, and minimizes resistance to energy reforms.

Third, enhancing transparency and accountability is critical. This includes publishing procurement frameworks, clarifying tariff structures, and regularly auditing project outcomes. Capacity-building efforts, through training, knowledge exchange, and institutional strengthening, must accompany these measures to ensure implementation effectiveness. By embedding these principles into national energy strategies, stakeholders can institutionalize public-private cooperation as a default mode of governance. Doing so will not only accelerate renewable energy adoption but also help shape a sustainable, inclusive, and resilient energy future.

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