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Government Support, PPP Financing Structure and Geothermal Energy Project Completion in Sub-Saharan Africa: Gaps and Lessons Learned from Kenya

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Abstract

Geothermal energy is a strategic resource in Kenya's energy strategy, but its development is constrained by intertwined technical, socio-political, and financial risks. Despite the increasing reliance on public private partnership (PPP) financing and procurement mechanisms for large-scale projects in Kenya, the execution and completion success of geothermal energy development remains highly variable, raising fundamental institutional, policy, and regulatory concerns. This presents a critical research void in understanding the effectiveness of government support in PPP frameworks within Sub-Saharan Africa, given the existing systemic governance and policy challenges. The study, therefore, aims to examine the extent to which government support measures moderate the relationship between PPP financing structures and project completion, drawing from Kenyan lessons and experience in geothermal energy development.

To address this, the study employed a mixed-methods research design, integrating a cross-sectional survey of 48 licensed geothermal projects with key informant interviews involving policymakers, investors, financiers, and developers in Kenya. Structured questionnaires anchored on a Likert scale provided quantitative insights, while interview data supplied qualitative depth. Data analysis incorporated descriptive statistics, regression modelling, and moderation analysis to evaluate the interaction between PPP financing structures, government support measures, and project completion outcomes.

The findings demonstrated that the Kenyan PPP financing structure, particularly comprising public equity and commercial debt, significantly influenced project completion. Furthermore, hybrid or mezzanine financing showed enhanced effectiveness when supported by complementary government support. Importantly, government support strongly influenced PPP financing structures through institutional mandates, feed-in-tariff policies,

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standardized power purchase agreement (PPA) frameworks, and regulatory guidelines in completing projects. The findings carry significant implications. From a policy perspective, they underscore the necessity of robust state support mechanisms, adaptive PPP frameworks, feed-in-tariff policies, and targeted regulatory reforms to improve project completion outcomes. Theoretically, the findings reinforce the position of Public Choice, Agency, and Systems theories in illustrating the interplay between state interventions, financing structures, and PPP project completion. Overall, these results advance scholarly and practical understanding of geothermal energy project management, offering guidance for policymakers and practitioners seeking to accelerate energy transitions in developing and emerging economies.

Keywords: Geothermal Energy Project, Public–Private Partnership (PPP) Financing Structure, Government Support, Project Completion, Sub-Saharan Africa, Kenya.

I. Introduction

Geothermal energy is regarded as a reliable baseload source that reduces dependence on hydropower, minimizes exposure to climate variability, and lowers electricity costs for sustainable industrial and household consumers (Baker & Sovacool, 2017; Kudtarkar, 2020). Despite this promise, geothermal projects are highly capital-intensive and often face barriers related to financing, technology, and risk allocation, especially in the Sub-Saharan Africa (SSA) region (Omenda & Simiyu, 2015). Specifically, geothermal development is constrained by intertwined technical, socio-political, and financial risks, including heavy front-loaded capital requirements and uncertainty in resource discovery (Liu & Lin, 2025). There is a documented need for green energy developers to prioritize delivery capabilities in emerging areas of innovation, as well as environmental and institutional integrity, to accelerate project completion and achieve greater impact and sustainability outcomes (Tan et al., 2024).

For over two decades, Public–Private Partnerships (PPPs) have been adopted globally as viable financing options for large-scale energy infrastructure projects (Yescombe, 2017; Osei-Kyei & Chan, 2015; Olejede et al, 2020; Du et al, 2019). Through PPPs, governments and private investors share risks, pool resources, and achieve efficiency gains in project delivery. Financing for renewable energy PPPs includes debt–equity combinations, hybrid arrangements, and grants from diverse sources. The efficacy of these structures largely determines the timely completion of projects, as financial misalignments or unbalanced risk-sharing often result in cost overruns and project delays (Grimsey & Lewis, 2004; Hodge & Greve, 2017; Du et al, 2019). Structural choice is therefore critical for bankability and project outcomes, particularly given the competitive and demanding nature of securing appropriate financing (Moore & Gutiérrez-Negrín, 2025).

Government support measures are consistently recognized as a decisive factor in the success of PPP-financed infrastructure projects. Such support extends beyond direct financial contributions to include regulatory frameworks, guarantees, standardized Power Purchase Agreements (PPAs), and policy incentives that enhance investor confidence and reduce project risks (World Bank Group, 2018; Yescombe & Farquharson, 2018; Olando et al., 2024a). This necessity is reflected in the requirement for governments to establish new policy, legal, and institutional frameworks to enable effective risk-sharing and attract investment (Prasad et al., 2024; Ibrahimi & Ilollari, 2025). In the geothermal sector, where exploration and drilling risks are substantial, government support is particularly significant in shaping the nexus between PPP financing and project completion (Eberhard & Gratwick, 2011). Furthermore, the SSA context specifically highlights regulatory uncertainty, weak enforcement, and political instability as persistent obstacles to market effectiveness (Olaniyi et al., 2025; Moyo & Oree, 2024).

Kenya is arguably the pioneer of geothermal development in Africa, with initial exploration and resource development traceable to the 1980s. The country is endowed with substantial geothermal potential, estimated at over 10,000 MW (Ouma et al., 2021). With the completion of the 45 MW Olkaria I power plant in 1985 (KenGen, 2021), geothermal energy has remained at the core of the national strategy for a sustainable and affordable energy transition, contributing approximately 45% of the country's electricity generation mix (EPRA, 2023). Nevertheless, the country has yet to join the global 1,000 MW geothermal club, indicating mixed performance that warrants further investigation. This positions Kenya as an appropriate case study for geothermal development across the SSA region.

The current research arises from persistent challenges experienced in the financing, implementation, and completion of geothermal projects in the Sub-Saharan Africa context, with Kenya used as a case study. Despite the widespread adoption of PPP financing mechanisms in large-scale energy initiatives, evidence indicates that many projects experience delayed completion, financing gaps, institutional bottlenecks, and, in some cases, ultimate failure (Mutinda, 2020; Kiplagat, 2021). This high variability in execution and completion success raises fundamental institutional, policy, and regulatory concerns. Previous studies have established the significant contribution of PPPs to energy infrastructure and consistently highlighted the importance of government support in renewable energy investments (Osei-Kyei & Chan, 2017; Bayliss & Van Waeyenberge, 2018; Chileshe et al.,

2020; Di Liddo et al., 2019). However, a critical research gap remains, as there is limited empirical evidence examining the influence of government support on the relationship between PPP financing structures and project completion in the geothermal energy sector, particularly within the challenging Sub-Saharan African context.
Additionally, the specific mechanisms through which government support interacts with the choice of PPP financing structure to ensure project completion remain largely underexplored (Liu & Lin, 2025). This gap is particularly pronounced given the persistent regulatory uncertainty, weak enforcement, and systemic governance challenges that characterize the SSA region, often constraining the effectiveness of policy measures (Olaniyi et al., 2025; Moyo & Oree, 2024). Furthermore, while existing literature acknowledges the systemic policy challenges that contribute to project failures (Moyo & Oree, 2024), there remains a distinct gap in quantifying the precise contribution of government support measures in mitigating the risk of delays inherent in PPP financing frameworks. This lack of quantifiable evidence limits policymakers' ability to design targeted interventions. Based on the foregoing, the study analysed the effectiveness of government support measures in moderating the association between PPP financing structures and the completion of geothermal energy development projects in Kenya.
By addressing the research objective, the study contributes to the progressive development of theory and project management practice. Theoretically, it enhances understanding of how institutional and policy frameworks interact with financial arrangements to influence infrastructure outcomes (North, 1990; Williamson, 1996). The focus on moderation within the SSA context therefore offers an original perspective on ongoing debates in renewable energy financing and governance. Practically, the study provides insights for policymakers, investors, financiers, and developers on designing PPP models that maximize project completion outcomes and accelerate the renewable energy transition, particularly in developing and emerging economies (World Bank Group, 2018; Olando et al., 2025). As such, the findings offer guidance for the formulation of state mechanisms necessary to unlock private capital, facilitate efficient delivery, and ensure the timely completion of large-scale geothermal energy development projects across SSA countries.

II. Literature Review

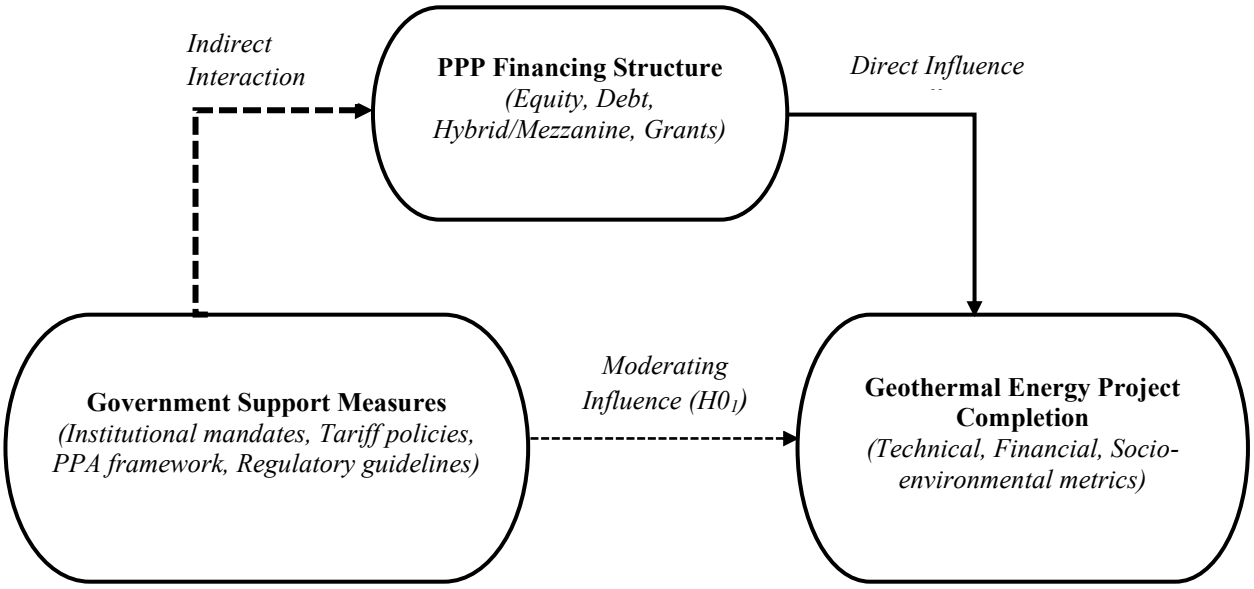
This study is grounded in three theoretical perspectives: Public Choice theory, Agency theory, and Systems theory. Public Choice theory emphasizes the role of government in providing public goods and correcting market failures through policies and institutional arrangements (Buchanan & Tullock, 1962; Mueller, 2003). In the context of PPPs, Public Choice insights explain the rationale for state involvement in financing and supporting geothermal projects, particularly given the high upfront risks that discourage purely private investment.
Agency theory highlights conflicts of interest between principals (governments and investors) and agents (project developers and contractors) within PPP arrangements (Jensen & Meckling, 1976; Eisenhardt, 1989; Olando et al., 2024b). Misaligned incentives and information asymmetry can lead to project inefficiencies, cost escalation, and delays unless robust governance and monitoring mjechanisms are established.
Systems theory adopts a holistic perspective by treating PPP-financed geothermal projects as complex socio-technical systems composed of interdependent components, including institutions, financing structures, technology, and regulatory mechanisms (Von Bertalanffy, 1968; Jackson, 2000). This systems-based approach supports the argument that government support enhances coherence across subsystems necessary for successful project completion. PPP financing structures for large-scale energy projects typically combine equity, debt, mezzanine instruments, and grants (Yescombe, 2017; Grimsey & Lewis, 2004).
Equity contributions by private sponsors are critical for signaling commitment and absorbing residual risks (Hodge & Greve, 2017). Debt financing through commercial banks, development finance institutions (DFIs), or green bonds provides leverage but often requires government guarantees or stable cash-flow frameworks to ensure bankability (World Bank Group, 2018). Hybrid or mezzanine financing structures, which blend debt and equity, offer flexible repayment arrangements suitable for projects with long gestation periods, such as geothermal energy (Ehlers, 2014). In some cases, grants and concessional finance are introduced to de-risk exploration and drilling phases, particularly in developing countries facing high geological uncertainty (Eberhard & Gratwick, 2011).
Accordingly, government support mechanisms significantly influence the effectiveness of PPP financing structures. Institutional mandates, such as dedicated PPP units and regulators, enhance credibility, facilitate coordination among sector stakeholders, and improve the overall investment environment (Osei-Kyei & Chan, 2017; Kepher et al., 2024). Tariff policies, including feed-in tariffs, provide predictable revenue streams and attract private investors (OECD, 2020).
Power Purchase Agreements (PPAs), particularly when supported by sovereign guarantees, secure long-term off-take arrangements and mitigate market risks (Yescombe & Farquharson, 2018). Regulatory guidelines such as licensing frameworks and environmental compliance standards also play a critical role in aligning private incentives with public objectives (Bayliss & Van Waeyenberge, 2018). In Kenya, these support measures have been applied within the geothermal sector, albeit with ongoing challenges related to policy consistency and institutional coordination (Ngugi, 2019).

Empirical evidence globally confirms that PPPs can enhance infrastructure provision when financing structures are well designed and supported by effective government frameworks. In Asia, Osei-Kyei and Chan (2015) identified government support and appropriate financial arrangements as critical success factors for PPP infrastructure projects. In Europe, Grimsey and Lewis (2004) emphasized the balance between debt and equity in determining PPP sustainability. Studies in Sub-Saharan Africa highlight that government-backed guarantees and concessional funding are indispensable for renewable energy projects due to elevated country and resource risks (Eberhard & Gratwick, 2011; Baker & Sovacool, 2017; Jagboro et al., 2020). Regionally, Kenya, Ethiopia, and Tanzania have made progress in geothermal and hydropower PPPs, although challenges persist. Mutinda (2020) reported ongoing financing gaps and project delays in Kenya despite strong policy commitments, while Kiplagat (2021) observed that renewable energy PPP projects in East Africa continue to rely heavily on donor-backed guarantees and subsidies, limiting scalability and long-term sustainability.

Although the literature acknowledges the importance of PPPs and government support in renewable energy development, several gaps remain. First, most studies focus on general infrastructure sectors such as roads, water, and ICT rather than the distinct financing and risk characteristics of geothermal projects (Osei-Kyei & Chan, 2017; Bayliss & Van Waeyenberge, 2018). Second, empirical research frequently aggregates renewable energy sources, thereby obscuring sector-specific dynamics and insights (Yang et al., 2024; Kiplagat, 2021; Maposa & Munanga, 2021). Third, limited attention has been given to the moderating role of government support in the relationship between PPP financing structures and project completion, particularly in geothermal projects characterized by high exploration risks (Kanyamyoga, 2020; Othman & Khallaf, 2022). This gap highlights the need for empirical studies focused on Kenya's geothermal sector, where PPP financing structures and government support may interact in complex ways to determine project completion outcomes.

Figure 1 presents a conceptual framework that integrates insights from Public Choice theory (Buchanan & Tullock, 1962), Agency theory (Jensen & Meckling, 1976), Systems theory (Von Bertalanffy, 1968), and key findings from the literature review. To complement these theoretical perspectives, the dynamic capability framework proposed by Teece, Pisano, and Shuen (1997) is also considered informative.

Figure 1. Conceptual Model



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The PPP financing structure comprising equity (public and/or private), debt (concessional and/or commercial loans), mezzanine or hybrid financing, and grants (government and/or development partners) constitutes the primary independent variable influencing the completion of geothermal energy projects in Kenya. However, the effectiveness of these financing structures is not uniform, as it depends heavily on the extent of government support. Government support includes institutional mandates, tariff and pricing policies, Power Purchase Agreements (PPAs), and regulatory guidelines (Yescombe, 2017; Osei-Kyei & Chan, 2017). By lowering risks and ensuring predictable returns, government interventions are expected to moderate the relationship between financing structures and project completion.

Consistent with Systems theory, the model conceptualizes project completion as the dependent variable an emergent outcome of interdependent subsystems, including financing, institutions, and regulations, working in alignment (Jackson, 2000). Accordingly, the framework positions government support as a critical moderating variable that conditions the impact of financing structures on project completion.

Relationships between the variables

The model posits a direct influence of PPP financing structures on geothermal energy project completion, while government support measures may either strengthen or weaken the influence of PPP financing structures on project completion. Prior studies suggest that well-structured financing significantly contributes to PPP project success; however, financing alone is insufficient without government-backed risk mitigation mechanisms (Grimsey & Lewis, 2004; Hodge & Greve, 2017). Empirical evidence from Sub-Saharan Africa indicates that sovereign guarantees, concessional finance, and regulatory clarity are critical to infrastructure delivery (Eberhard & Gratwick, 2011; Baker & Sovacool, 2017).

In geothermal projects, high exploration and drilling risks create financing barriers that can only be addressed when governments provide tariff incentives, PPA guarantees, and enabling regulatory frameworks (Ngugi, 2019; Mutinda, 2020). This suggests that government support does not function merely as a control variable, but rather as a moderating factor that conditions how financing structures translate into completed projects. Accordingly, this study tests the following null hypothesis:

H01: Government support measures do not significantly moderate the relationship between PPP financing structure and the completion of geothermal energy development projects in Kenya.

III. Methodology

The study utilized a mixed-methods approach, grounded in positivist and pragmatic philosophical foundations. The positivist school of thought emphasizes the use of objective, observable, and measurable data to explain relationships among variables (Creswell & Creswell, 2018). Positivism was complemented by pragmatic assertions, enabling the integration of both quantitative and qualitative insights to generate a comprehensive understanding of the research problem (Tashakkori & Teddlie, 2010). This hybrid paradigm ensured rigor in testing hypothesized relationships while allowing contextual interpretation of geothermal project implementation dynamics in Kenya (Johnson & Onwuegbuzie, 2004).

A cross-sectional survey design was employed to capture data at a single point in time from multiple geothermal energy projects. This design facilitates the analysis of correlations between financing structures, government support, and project completion (Saunders, Lewis, & Thornhill, 2019). To enrich the survey findings, provide qualitative depth, and validate the quantitative results, key informant interviews were also conducted with senior directors from relevant sector agencies, the PPP Directorate, financing institutions, as well as research and academic institutions.

The unit of analysis comprised all 48 geothermal energy projects licensed in Kenya as of 2022 (EPRA, 2023). According to Stuart, Bradshaw, and Leaf (2015), this census approach minimized sampling error and ensured maximum generalizability of the findings to the geothermal sector in Kenya and across Sub-Saharan Africa. In addition, the unit of observation included 96 purposively selected officers drawn from project management and finance functions, as well as five key informants purposively selected from regulatory authorities, including the Geothermal Development Company and EPRA.

This approach enabled the inclusion of personnel with direct oversight of project scheduling and completion milestones, as well as financial expertise related to debt equity structures, financing gaps, risk mitigation, and regulatory instruments.

Regarding data collection tools, the study employed a structured questionnaire to capture Likert-scale perception scores on PPP financing mechanisms, government support measures, and project completion metrics from project managers and financial officers. In addition, a key informant interview guide was used to capture regulatory perspectives and qualitatively supplement the questionnaire's quantitative data. Yusof et al. (2019) emphasize that Likert-scale questionnaires are easy to administer and do not interfere with respondents' regular routines.

The study operationalized its three core constructs as follows. Project completion served as the dependent variable and was measured in terms of project completion status, drawing conceptually from the literature on project success and failure in infrastructure development (Hodge & Greve, 2017; Liu & Lin, 2025). The PPP financing structure, which constituted the independent variable, was operationalized using indicators such as equity, debt, hybrid or mezzanine financing, and grants, consistent with PPP financing and bankability models (Yescombe, 2017; Moore & Gutiérrez-Negrín, 2025).

Government support measures represented the moderating variable and were operationalized through indicators including Power Purchase Agreements (PPAs), tariff policies, regulatory guidelines, and institutional mandates, based on established energy-sector literature (World Bank Group, 2018; Yescombe & Farquharson, 2018; Eberhard & Gratwick, 2011). The measurement scale for all three variables was a five-point Likert scale.

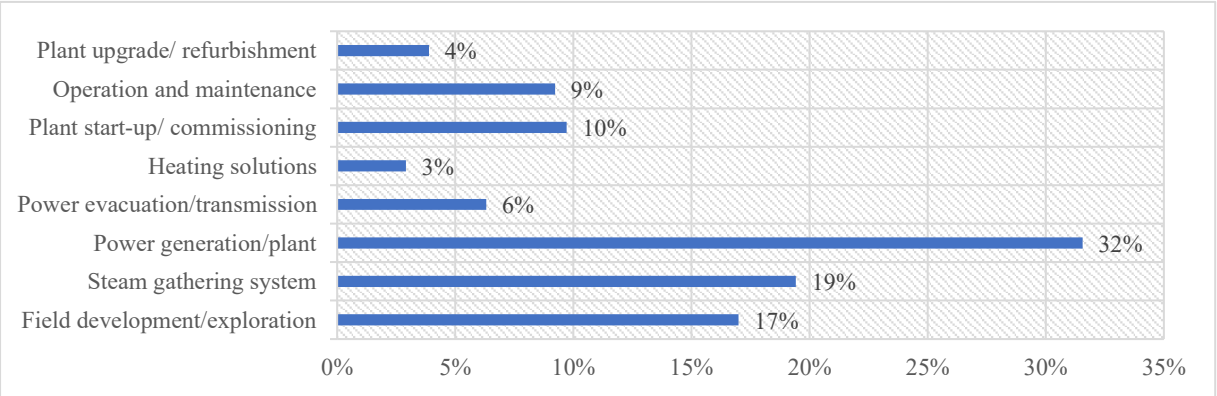
Quantitative data were analyzed using descriptive statistics, including means, frequencies, and standard deviations, to summarize project characteristics and respondent perceptions. Inferential analysis involved the development of stepwise regression models to establish the direct effect of PPP financing mechanisms on project completion (Hair et al., 2018). The moderating effect of government support measures was tested using interaction terms, following the procedures outlined by Baron and Kenny (1986). Statistical significance was set at $p < 0.05$,

and the interaction effect of government support measures on the relationship between the independent and dependent variables was examined.
Qualitative interview data were thematically analyzed to contextualize the quantitative findings and to support data triangulation.

IV. Results and Discussion of Findings

The descriptive statistics summarize responses obtained from managers (team leaders) of 48 geothermal energy projects licensed in Kenya. The study achieved a response rate of 81.7%, which exceeds commonly accepted benchmarks for survey-based studies, including 50% suggested by Baruch and Holtom (2008) and 60% proposed by Fincham (2008).
The study further provides a comprehensive overview of the types and scopes of geothermal energy projects in Kenya, capturing the key components and development phases involved in geothermal project implementation. As illustrated in Figure 2, the projects encompass multiple stages and technical configurations that reflect the complexity of geothermal energy development in the Kenyan context.

Figure 2. Types of Geothermal Energy Projects



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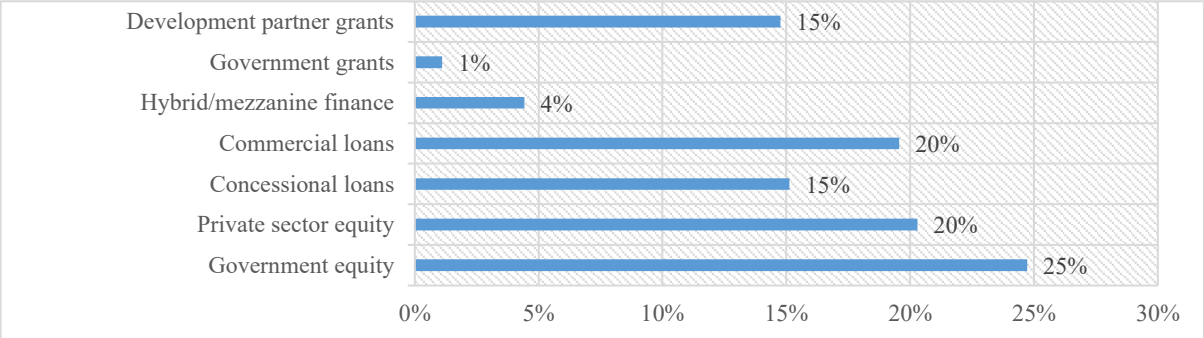
The results indicate that power generation and plant development are predominant (32%), underscoring the primary objective of harnessing the Earth's heat for electricity production. This reflects the capital-intensive nature of constructing and maintaining geothermal power plants. The substantial focus on steam gathering systems (19%) and field development or exploration (17) which are critical precursors highlights the challenging and resource-intensive nature of geothermal exploration and resource management. This finding aligns with Kombe (2018), who emphasized the role of government support in mitigating exploration risks in East African projects. The emphasis on the operational aspects of geothermal plants (19%) further indicates recognition of the long-term nature of these projects.
Power evacuation and transmission, contributing 6%, suggest that this infrastructure component may be less of a bottleneck, potentially benefiting from existing grid systems. The relatively low allocation to plant upgrades or refurbishment (4%) may indicate that many projects remain in their early stages of development. Heating solutions account for only 3% of project focus, a notably low proportion when compared to countries such as Iceland or New Zealand, where direct-use applications are more prevalent. As Lund and Boyd (2016) observe in their global review of geothermal direct utilization, many countries extensively leverage geothermal resources for space heating, greenhouse cultivation, and industrial processes. The limited focus on heating solutions in Kenya therefore presents an opportunity for future diversification beyond electricity generation, particularly in the context of global green industrialization investments.
Project budgets range from as low as US$800,000 to as high as US$800 million, with most projects falling between US$100 million and US$500 million. A standard deviation of US$150.6 million indicates substantial variability in project size and scope. Although the average estimated budget is US$117.6 million, the median value of US$150 million suggests that the majority of projects are clustered within the US$100 million to US$500 million range.
With respect to implementation periods, the data indicate a predominant project duration of between 37 and 48 months, accounting for 30.7% of the projects examined. This modal duration suggests an industry-standard expectation for project completion, potentially reflecting regulatory frameworks, technological constraints, or prevailing resource allocation practices. Notably, a substantial proportion of projects (21.93%) require extended

implementation periods of 49 to 60 months. Such prolongation may be indicative of project complexity, unforeseen geotechnical challenges, or systemic inefficiencies in project management and execution. Conversely, a smaller share of projects (7.02%) exhibits accelerated implementation periods of 12–24 months, while an additional minority (6.15%) requires more than 61 months for completion. This wide variation in implementation timelines underscores the heterogeneous nature of geothermal projects, likely influenced by site-specific geological conditions, technological sophistication, and differences in project scale and scope.

Regarding financing sources, government equity constitutes the largest share (25%), followed by private equity (20%), commercial loans (20%), concessional loans (15%), hybrid or mezzanine financing (4%), and grants (1%), as illustrated in Figure 3.

Figure 3: Geothermal PPP Financing Sources



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The financing structures demonstrate a well-balanced PPP approach to geothermal development in Kenya. Substantial government equity participation (25%), alongside significant private sector involvement (a combined 40% from private equity and commercial loans), exemplifies a classic PPP model in which risks and rewards are shared. This structure aligns with the findings of Ndiritu and Engola (2020), who emphasized the importance of PPPs in driving geothermal development in East Africa. A minimal proportion of government grants (1%) suggests a preference by state agencies for equity participation rather than direct subsidies, as also noted by Bergek et al. (2013).

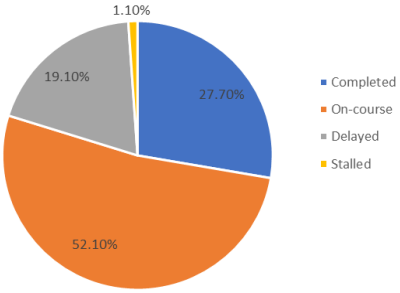
The combination of commercial and concessional loans (35%) underscores the importance of debt financing in this high-risk and capital-intensive sector. The presence of concessional loans reflects efforts to improve financing accessibility and affordability. Development partner grants account for a notable 15%, indicating strong international support for Kenya's geothermal development agenda, consistent with global initiatives promoting renewable energy in developing economies. Hybrid or mezzanine financing, although relatively small at 4%, indicates some appetite for more complex financial instruments, potentially to bridge gaps between equity and debt financing.

Analysis of responses from project managers and team leaders further illustrates the structure of PPP financing in geothermal projects. Equity financing accounted for 32% of total project funding, while debt financing comprised 41%. Hybrid or mezzanine financing contributed 19%, with grants covering the remaining 8%. These findings indicate a dominant reliance on debt and equity mechanisms, consistent with evidence from similar infrastructure projects across Sub-Saharan Africa (World Bank Group, 2020).

Regarding government support measures, respondents reported moderate to high levels of influence across key indicators. Institutional mandates and tariff policies recorded mean scores of 3.8 and 4.0, respectively, on a five-point Likert scale. Power Purchase Agreement (PPA) frameworks were perceived as the most effective form of government support (M = 4.2), while regulatory guidelines recorded an average score of 3.6. These results suggest that government interventions are widely perceived as essential enablers of project viability and completion (Ngugi & Mwangi, 2021).

With respect to project completion status, the analysis indicates that 27.7% of the surveyed projects were rated as satisfactorily complete, 52.1% were on course, and 20.2% were either delayed or stalled, as illustrated in Figure 4.

Figure 4. Project Completion Status



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The high proportion of projects that are on course (52.1%) reflects a proactive approach to government support, project governance and management, as well as resource allocation. This finding aligns with studies on renewable energy project management, which emphasize the importance of continuous monitoring and adaptive strategies in ensuring timely project delivery (Baker et al., 2019).

Projects experiencing delays (19.1%) indicate persistent challenges within the geothermal project life cycle, including financial constraints, technical complexities, regulatory hurdles, and environmental considerations. The prevalence of delays is consistent with broader challenges documented in energy infrastructure projects across developing countries, where financial and regulatory environments frequently present substantial obstacles (World Bank Group, 2020; UNEP, 2021). Addressing such delays requires targeted interventions, including improved project planning, enhanced stakeholder engagement, and more efficient regulatory processes.

Although the proportion of stalled projects (1.1%) is relatively low, such outcomes may result from severe funding shortages, unresolved technical constraints, or significant policy shifts. Similar patterns have been observed in large-scale infrastructure projects, where unforeseen risks or changes in economic and political conditions adversely affect project progress. Minimizing the likelihood of project stalling therefore necessitates robust risk management strategies and agile project management frameworks.

To examine the relationships between PPP financing structures, government support measures, and geothermal project completion, a stepwise multiple regression analysis was conducted. The results of this analysis are summarized in Table 1. In particular, Table 1(a) presents the model fit statistics and the predictive power of the estimated regression models.

Table 1(a). Model Summary

Model	Predictors Included	R	R^2	Adjusted R^2	R^2 (Change)	F Change	Sig. F Change
1	PPP Financing Structure	.663	.439	.433	.439	72.114	.000
2	PPP Financing Structure + Government Support Moderation	.708	.501	.490	.062	9.771*	.001

Note: Author's own work

Table 1(b). ANOVA Results

Model	Sum of Squares (Regression)	df	Mean Square	F	Sig.
1	18.983	1	18.983	72.114	.000
2	21.661	2	10.830	45.754	.000

Note: Author's own work

Table 1(c). Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig. (p)	Collinearity Statistics	
		β	Std. Error	β			Tolerance	VIF
1	(Constant)	0.624	0.397	---	1.575	0.119		---
	PPP Financing Structure	0.875	0.103	0.663	8.492	0	1	1
2	(Constant)	1.566	0.469	---	3.34	0.001		---
	PPP Financing Structure	0.171	0.231	0.13	0.74	0.461	0.179	2.491
	Government Support	0.118	0.035	0.589	3.363	0.001	0.179	2.491

Note: Author's own work

The results establish a direct influence of the PPP financing structure, explaining a substantial 43.9% of the variance in project completion ($R^2 = 0.439$). The introduction of government support as a moderating variable in Model 2 significantly improved the model fit. The total variance explained increased to 50.1% ($R^2 = 0.501$), yielding a statistically significant R^2 change (ΔR^2) of 0.062, with a corresponding significance level of Sig. F Change = 0.001. This ΔR^2 confirms that the moderation effect provides a significant incremental contribution to predicting project completion outcomes.

In addition, the results presented in Table 1(b) confirm the overall statistical significance of both regression models. The ANOVA results indicate that both the direct-effect model (Model 1) and the moderation model (Model 2) are highly statistically significant ($p < 0.001$). The F-statistics for both models demonstrate that the variation explained by the predictor variables is significantly greater than the unexplained (residual) variation, thereby validating the suitability of the models for hypothesis testing.

With respect to the regression coefficients reported in Table 1(c), the results provide detailed information on the magnitude, direction, and statistical significance of each predictor included in the models. Specifically, Model 1 indicates that the PPP financing structure is a strong, positive, and statistically significant predictor of project completion ($\beta = 0.663$, $p < 0.001$). This implies that a one-unit increase in the standardized PPP financing structure is associated with a 0.663-unit increase in the standardized project completion outcome. The resulting regression equation (I) is presented as follows:

Regression Equation (I)
Geothermal Energy Project Completion = 0.624+0.875*PPP Financing Structure.

This equation suggests that for every one-unit increase in the PPP financing structure score, geothermal project completion increases by an average of 0.875 units (Wooldridge, 2015). The constant term (0.624) represents the expected level of project completion when the financing structure score is zero; however, its p-value (0.119) is not statistically significant at the conventional 0.05 level, indicating that the intercept is not statistically different from zero (Field, 2013). Although the model explains a substantial proportion of the variance, more than half (56.1%) remains unexplained. This suggests that additional factors not included in the model also play important roles in determining the completion of geothermal development projects. Such factors may include technological conditions, government support and regulatory environments, geological characteristics, delivery capability, and other project-specific variables (DiPippo, 2016; Olando et al., 2024a), all of which influence project completion. The relevance of these unmodeled risk factors is further underscored by recent studies highlighting the intertwined technical, socio-political, and financial risks inherent in geothermal development (Liu & Lin, 2025; Akram et al., 2023).

Model 2 further examined the moderating effect of government support measures on the relationship between PPP financing mechanisms and project completion. While the R^2 change reported in Table 1(a) confirms the presence of an overall moderation effect, the regression coefficients indicate that the government support moderation variable itself is a highly significant predictor of project completion ($\beta = 0.589$, $p = 0.001$). The standardized beta coefficient for government support ($\beta = 0.589$) is strong and positive, exceeding the coefficient associated with the PPP financing structure alone ($\beta = 0.103$). This strong moderating influence is conceptually consistent with the global PPP literature, which emphasizes the need for governments to establish supportive policy, legal, and institutional frameworks to enable effective risk-sharing and attract private investment (Prasad et al., 2024; Ibrahimi & Ilollari, 2025).

Specifically, projects characterized by stronger institutional mandates and supportive tariff policies exhibit a more pronounced positive relationship between debt and equity financing and project completion rates. Similarly, robust PPA frameworks enhance the effectiveness of hybrid financing structures. These findings suggest that government support not only complements financing structures but also strengthens their capacity to drive project completion outcomes (Asare & Prempeh, 2022), particularly by mitigating challenges such as regulatory

uncertainty and limited institutional capacity prevalent in Sub-Saharan African energy markets (Olaniyi et al., 2025; Moyo & Oree, 2024). The resulting regression equation (II) is presented as follows:

Regression Equation (II)
Geothermal Energy Project Completion = 1.566 + 0.171* *PPP Financing Structure*+0.118 **Government Support.*

Equation 1 suggests that for every one-unit increase in the PPP financing structure score, geothermal project completion increases by an average of 0.171 units, while a one-unit increase in government support moderation is associated with a 0.118-unit increase in geothermal project completion (Wooldridge, 2015). The constant term (1.566) represents the expected level of project completion when both predictor variables are zero. Its p-value (0.001) is statistically significant, indicating that the intercept is significantly different from zero (Field, 2013). The proportion of explained variance (50.1%) underscores the importance of both financing structures and government support in determining project completion outcomes. This finding is consistent with previous research emphasizing the benefits of PPPs in terms of risk sharing and project viability (Yescombe & Farquharson, 2018), as well as the critical role of government support in facilitating renewable energy development (Edenhofer et al., 2011). Based on these results, the study rejected H01 which stated that government support measures do not significantly moderate the relationship between PPP financing structures and the completion of geothermal energy development projects in Kenya and instead accepted H11, indicating that government support provides critical moderating leverage.

While the explained variance is substantial, the remaining unexplained variance (49.9%) is also noteworthy, suggesting that additional factors beyond the scope of the study's hypothesis may significantly influence project completion. Prior studies indicate that factors such as developers' delivery capability and ecological conditions play important roles in determining geothermal project outcomes (Olando et al., 2025). This highlights the multifaceted nature of geothermal project completion and the presence of complementary determinants beyond financing structures and government support.

A range of diagnostic tests was conducted to ensure the robustness of the regression results. Variance Inflation Factor (VIF) values were below 2.5, confirming the absence of multicollinearity. The Breusch–Pagan test for heteroscedasticity was non-significant ($p > 0.05$), indicating homoscedastic residuals. Residual diagnostics further confirmed the normality and independence of errors, supporting the appropriateness of the regression model. In addition, sensitivity analyses using alternative model specifications produced consistent results, thereby confirming the stability of the findings (Gujarati & Porter, 2009).

The qualitative findings strongly suggest that policies and initiatives aimed at enhancing government support are critical to maximizing the effectiveness of PPP financing structures. Data obtained from key informant interviews provided valuable contextual insights into the quantitative results. While PPPs are generally perceived as successful in Kenya, respondents raised concerns regarding the underestimation of geological risks and the need for improved risk allocation mechanisms.

The preferred financing mix was reported to comprise private equity, commercial loans, and development finance institutions (DFIs), with government contributions typically ranging between 5% and 15%. Government support mechanisms were identified as including tax incentives, regulatory frameworks, and Power Purchase Agreements (PPAs). However, informants also expressed concerns related to bureaucratic processes, limited fiscal space, and the cost-effectiveness of certain government support measures.

Overall, the strong alignment between the qualitative insights and the statistical results reinforces the conclusion that PPP financing structures and government support play a crucial role in driving successful geothermal project completion outcomes.

V. Conclusion and Recommendatio

Guided by the research questions, the findings demonstrate that the PPP financing structure has a positive and statistically significant influence on geothermal project completion ($\beta = 0.663$, $p < 0.001$). This directly addresses the primary research question concerning the role of financing structures. However, the analysis further reveals that the direct effect of financing structures weakens once government support is incorporated into the model. Instead, government support emerges as a strong, positive, and statistically significant determinant of project completion ($\beta = 0.589$, $p = 0.001$), underscoring its central role in shaping project outcomes. Consequently, there is compelling empirical evidence to reject the null hypothesis (H01), confirming that government support measures significantly strengthen (moderate) the relationship between PPP financing structures and project completion ($\Delta R^2 = 0.062$, $p = 0.001$). These findings validate the hypothesized moderating effect and confirm the expected causal mechanism.

The distribution of activities across the various stages of geothermal development from exploration to operation and maintenance highlights the importance of targeted government support and diverse delivery capabilities throughout the project life cycle. When compared with global trends, the results reveal both convergence and divergence. Bertani's (2016) global review of geothermal power generation confirms a predominant focus on electricity production, which aligns with Kenya's emphasis on power generation. However, Kenya's limited engagement in direct-use applications contrasts with the growing diversification of geothermal utilization observed in countries such as Turkey, China, and the United States (Lund & Boyd, 2016).

The strong emphasis on field development and exploration in Kenya (17%) reflects a response to globally recognized challenges associated with geothermal resource assessment, characterized by high uncertainty and substantial upfront risk. These challenges often necessitate government involvement to attract private investment. Goldstein et al. (2012), in the IPCC special report, similarly highlight exploration and resource confirmation as major barriers to geothermal development worldwide. Kenya's focus in this area therefore suggests a proactive approach to addressing these structural constraints.

The findings provide valuable insights into the structuring and prioritization of PPP arrangements within Kenya's geothermal sector. They highlight the areas in which PPP financing and government support are most critical, particularly in capital-intensive and high-risk phases such as resource exploration and power plant development. The observed distribution of project activities further underscores the complex and multi-dimensional nature of geothermal projects, reinforcing the suitability of PPP models for mobilizing diverse expertise, resources, and risk-sharing mechanisms.

In terms of project budgets, the large standard deviation of US$150.6 million reflects substantial variability in project scope and risk profiles, indicating a wide range of financial requirements across geothermal projects. While most projects fall within the US$100 million to US$500 million range, the presence of both smaller and significantly larger projects underscores the need for flexible and well-structured PPP arrangements tailored to specific project characteristics.

Similarly, variability in implementation periods evidenced by a standard deviation of 15.75 months suggests a degree of unpredictability in project timelines. This variability may be attributed to factors such as project scale, geological uncertainty, fluctuations in resource availability, and differences in regulatory approval processes. The presence of outliers, with implementation durations ranging from as short as 12 months to as long as 120 months, warrants further investigation, as these cases may offer valuable insights into best practices or persistent systemic challenges within geothermal energy development across the Sub-Saharan African region.

The distribution of project completion statuses within Kenya's geothermal sector reflects both strengths and areas requiring improvement. The 27.7% completion rate, while noteworthy, suggests scope for enhanced efficiency and stronger support mechanisms to increase successful project delivery. In comparison, regions with more mature geothermal industries such as Iceland and the Philippines exhibit higher completion rates, largely due to more established regulatory frameworks and support systems (IRENA, 2021). The substantial proportion of projects that are on course (52.1%) is encouraging, indicating active engagement and effective management practices. However, the presence of delayed projects (19.1%) points to systemic constraints that must be addressed to align performance with best practices observed in countries with high renewable energy project success rates (Baker et al., 2019). The relatively low incidence of stalled projects (1.1%) is a positive indicator, suggesting that although challenges exist, they seldom result in complete project cessation. This contrasts with large-scale infrastructure projects in other sectors, where stalling is more prevalent due to complex interdependencies and heightened risk exposure (World Bank Group, 2020).

The findings further demonstrate that government support plays a critical role in shaping the relationship between PPP financing structures and geothermal project completion. Although various government support measures are in place, the study highlights concerns related to bureaucratic procedures, limited fiscal space, political uncertainty, and the cost-effectiveness and efficiency of certain support mechanisms. These constraints underscore the need for continuous refinement of government interventions to enhance the effectiveness of PPP arrangements. The results reinforce the study's central argument that PPP financing structures and government support must be examined jointly to explain variations in project completion outcomes. Consistent with this view, Grimsey and Lewis (2007) argue that government actions such as providing guarantees, establishing predictable tariff regimes, and enforcing transparent regulatory frameworks reduce investor risk and strengthen project bankability.

In Kenya's geothermal sector, standardized Power Purchase Agreements and feed-in tariff mechanisms appear to amplify the effectiveness of equity and hybrid financing structures, echoing similar findings from renewable energy PPPs in Asia and Latin America (Delmon, 2017; IRENA, 2021). These results align with global evidence indicating that PPPs in renewable energy are most effective when coupled with robust state support mechanisms. For example, in India and Brazil, state-backed guarantees and tariff incentives have significantly improved renewable energy project completion rates (Mousinho et al., 2017; Alves, Ferreira, & Araújo, 2019). In contrast, projects lacking sustained government commitment frequently encounter delays or abandonment due to financing shortfalls and regulatory inconsistencies (World Bank Group, 2020). The Kenyan case thus illustrates that

government intervention is a necessary condition for PPP-led renewable energy transitions in developing economies, particularly within the Sub-Saharan African context.

A comparison of Kenya's PPP financing structures with global practices reveals both convergence and distinctive features. The relatively strong government role accounting for approximately 26% through combined equity and grants is higher than in many developed markets but consistent with trends observed in emerging economies. Eberhard and Naude (2017) similarly document significant government involvement in renewable energy financing across Sub-Saharan Africa. At the same time, the substantial private sector contribution (40% from equity and commercial loans) is encouraging and compares favorably with global averages. IRENA (2021) reports a global increase in private investment in renewable energy, particularly within emerging markets. The notable contribution from development partners (15% in grants) exceeds global averages and reflects the strategic importance of geothermal energy within Kenya's energy mix and climate objectives. The use of concessional loans (15%) further aligns with practices in other developing economies, where such instruments are widely recognized as essential for de-risking renewable energy investments (World Bank Group, 2018).

From a theoretical perspective, the findings offer important contributions. Within the Public Choice framework, government support represents strategic intervention aimed at reconciling private sector incentives with broader public welfare objectives, ensuring the provision of collective goods such as sustainable energy despite market imperfections (Buchanan & Tullock, 1962). From an Agency theory standpoint, government oversight mechanisms help mitigate information asymmetries and opportunistic behavior among financiers, developers, and regulators, thereby aligning project incentives and outcomes (Jensen & Meckling, 1976). The results also resonate strongly with Systems theory, illustrating the interdependence of institutional, financial, and technical subsystems in shaping geothermal project completion outcomes (Von Bertalanffy, 1968).

Most notably, this study provides one of the first empirical quantifications using Hierarchical Multiple Regression (HMR) of the moderating role of government policy instruments on PPP financing mechanisms within the geothermal energy sector in Sub-Saharan Africa. By moving beyond descriptive and correlational analyses, the study establishes clear directional and causal relationships, demonstrating that government intervention functions not merely as a prerequisite but as an amplifying mechanism for project success in complex energy systems. Collectively, these findings reinforce the conclusion that PPP financing structures and project completion outcomes cannot be fully understood in isolation from the enabling and coordinating role of government policy.

A realignment of policy focus on the geothermal energy sector is imperative. The unbundling of Kenya's energy sector institutional mandates covering regulation, development, production, evacuation and distribution, and retail across various state agencies has accelerated reforms over the past two decades. Nevertheless, government support mechanisms require further strengthening through the continuous enhancement of institutional effectiveness and the streamlining of PPP regulatory frameworks. To reduce the high perceived risks associated with resource exploration and development, scaling up investments in the delivery capabilities of the Geothermal Development Corporation (GDC) and related entities is critical. Predictable and transparent tariff policies are particularly important for reducing financing uncertainty and improving the bankability of geothermal investments (Grimsey & Lewis, 2007; IRENA, 2021). Policymakers should therefore consider adaptive PPP structures that incorporate risk-sharing arrangements, guarantees, and flexible financing models to attract diverse sources of capital. Regulatory reforms should also focus on harmonizing licensing, compliance, and monitoring procedures to lower transaction costs and improve project efficiency (Barber, 2015). Collectively, these measures would create a more conducive investment environment for scaling geothermal energy development in Kenya.

The findings further suggest that an integrated approach to geothermal project financing and governance is more pragmatic. While debt and equity remain the dominant financing mechanisms, their effectiveness in driving project completion is significantly enhanced when complemented by government interventions, including clearly defined institutional mandates, predictable feed-in-tariff regimes, and standardized Power Purchase Agreement frameworks. Grants exhibit limited direct influence on project completion, whereas hybrid or mezzanine financing structures benefit strongly from robust government support. The moderation analysis confirms that government action amplifies the positive effects of PPP financing structures on project completion, thereby reducing inherent risks and strengthening investor confidence.

From a practical perspective, the results carry important implications for key stakeholders. For investors, the findings indicate that equity- and debt-backed PPPs yield more favorable outcomes when supported by government guarantees and tariff stability. For project developers, close collaboration with government institutions is essential for navigating regulatory procedures and securing PPAs that provide revenue certainty. For policymakers, the results underscore the importance of aligning regulatory frameworks with market realities to sustain investor confidence and maintain project momentum. Effective PPP financing thus requires not only sound financial structuring but also consistent and credible government support.

The study also highlights the importance of adopting a holistic approach to measuring geothermal project completion. Beyond technical and financial considerations, the integration of socio-environmental metrics can play a critical role in mitigating stakeholder conflicts that may otherwise delay or stall projects, consistent with the observations of Wang et al. (2019). Investments in delivery capabilities including agile project management

practices, the use of advanced technologies such as artificial intelligence, the establishment of dedicated project delivery units, and the implementation of local benefit-sharing mechanisms represent additional strategic interventions that can enhance project outcomes.

Finally, while this study advances understanding of PPP financing dynamics in Kenya's geothermal sector, it also identifies opportunities for further research. Given that a substantial proportion of variance in project completion (49.9%) remains unexplained, future studies could explore additional determinants. These include the role of community engagement in PPP-led geothermal projects, which may shed light on the social sustainability of such initiatives, as well as the incorporation of delivery capability, environmental, and climate risk factors to better capture long-term project resilience. Moreover, cross-country comparative studies within Sub-Saharan Africa would enhance the generalizability of the findings and provide broader insights into regional renewable energy transitions. Collectively, these avenues offer promising directions for extending the knowledge base and informing both academic inquiry and policy development.

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Originality of the Research Paper

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