

Research Article

# The Synergistic Effect of PPP Financing Structure, Delivery Capability and Government Support on Completion of Geothermal Energy Development Projects in Kenya

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## Abstract

Despite increased adoption of the Independent Power Producer (IPP) variant of Public-Private Partnership (PPP), investments in Geothermal Energy Development Projects (GEPs) are still considered high-risk and capital-intensive while their completion remains unpredictable, especially in the Sub-Saharan Africa (SSA) region; some have delayed, stalled or failed, or grappled with governance and ethical issues amidst public outcry over value for money. Although previous scholars have published on geothermal projects in more than 20 countries, mostly developed and emerging economies, this study builds on existing conceptual, methodological and contextual gaps; it examines the joint effect of PPP financing structure, delivery capability and government support on GEP completion in Kenya. This investigation is especially relevant as Kenya possesses abundant geothermal resources estimated at over 10,000 megawatts, yet faces significant challenges in achieving desirable completion outcomes. The research employs a mixed-methods approach, combining descriptive, correlation and regression analysis of data collected on 42 licensed geothermal projects with qualitative insights from 10 key stakeholders across public, private, development, research, civil and academia sectors. Statistical analysis reveals a significant synergistic relationship between the three variables ( $R^2 = .663$ ,  $p < .001$ ), with delivery capability emerging as the strongest predictor ( $\beta = .607$ ,  $p < .001$ ), followed by PPP financing structure ( $\beta = .400$ ,  $p < .001$ ) and government support ( $\beta = .260$ ,  $p = .042$ ). This study offers multiple novel contributions: it provides the first empirical evidence of a synergistic effect of PPP financing structure, delivery capability and government support on GEP completion in the SSA context; determines the dominance of delivery capability, especially technical expertise, value maximization, and agile project management abilities; integrates the public choice, agency, dynamic capability and systems theoretical frameworks to present a synergistic model for the four variables; outlines best practice project monitoring and control measures of GEP completion; and presents opportunities for further research. These findings offer valuable guidance for policymakers and project developers while contributing additional knowledge to enhance geothermal energy development in Kenya and similar contexts.

## Keywords

Public-Private Partnership (PPP) Financing Structure, Government Support, Delivery Capability, Geothermal Energy Development Project Completion

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## 1. Introduction

The growing importance of private investment in renewable energy development reflects governments' understanding of its role in ensuring energy security [33]. The World Bank Group asserts that PPP agreements account for approximately 60% of new renewable energy capacity globally, with specialized financial instruments emerging to support these mega investments [79]. This paper investigates the interplay between PPP financing structure, delivery capability, government support and project completion in Kenya's context of geothermal energy development.

### 1.1. Africa's Dream of Joining the Global 1,000 Megawatts Club Has Taken Too Long

The East African Rift Valley (EARV) ecosystem offers enormous geothermal potential, estimated at 20,000 MW [58, 60]. Although Kenya leads the continent in tapping this resource, geothermal development faces unique hurdles. Although global geothermal exploration commenced in the 1950s, African nations initiated their efforts at a later stage. Despite East African countries' enthusiasm for policy reforms aimed at attracting private investments in renewable energy development, significant progress has yet to be realized [15, 26, 47, 48]. Kenya's 45 MW Olkaria I project was completed in 1985 as the pioneer GEP on the continent. Other countries pursuing geothermal prospects along the EARV corridor include Djibouti, Ethiopia, Tanzania, and Mozambique. Kenya's geothermal energy sector has experienced significant growth, becoming crucial for achieving national grid energy accessibility, reliability and sustainability; with estimated resources exceeding 10,000 megawatts, Kenya ranks among the top 10 global geothermal producers [33, 59]. Successive governments have strategically scaled up geothermal investments to address hydroelectricity limitations, notably frequent blackouts and price spikes during droughts [50]. The geothermal share of the national installed energy mix increased from below 10% in 2006 to 26% in 2023, the Energy and Regulatory Authority of Kenya (EPRA) is aiming for a target of 51% by 2030 [25]. After almost 60 years, only 5 of 14 (36%) prospective geothermal sites are operational and situated in sensitive ecosystems [57]. With Kenya's cumulative installed geothermal capacity at 949 MW, the African dream of joining the prestigious Global 1000 MW Geothermal Club remains unfulfilled 40 years later.

### 1.2. Demystifying the Research Problem

There is an ideological and intellectual dilemma in the practice of PPPs worldwide. The question of whether PPP projects yield improved cost performance, quality, value for money, project governance, risk management, advanced technologies, specialized skills and capacities remained debatable since the 1980s; for example, while some researchers

affirm that Public-Private Partnership (PPP) projects enhance cost performance, quality, and value for money, others argue that these projects are inherently complex, lengthy, and entail high transaction costs [5, 55, 71, 85]. The conditions for an ideal PPP financing structure have evolved over the last decade; there is a shift from ideological debates to fact-based evaluation of PPP financing in each infrastructure sector [43]. It is widely acknowledged that GEPs are complex, capital-intensive and high-risk investments requiring specialized delivery capabilities compared to solar and wind energy projects [35]; this reality makes their completion quite uncertain especially in emerging and developing economies, requiring targeted research to solve such problems. Each source of PPP financing portrays both merits and demerits implying possible inconsistency in their individual/and joint influence on the completion of GEPs; as such, project completion indicators should be responsive to the sector and contextual reality by including technical, financial and socio-environmental metrics [45, 55]. A current assessment of the situation of PPP projects in the SSA geothermal sector is expected to contribute additional sector-specific facts to the ongoing conceptual discourse.

In line with the East African Community Vision 2050, Africa Agenda 2063 and 2030 Agenda for Sustainable Development, Kenya envisions a middle-income economy enjoying the status of a Pan-African commercial and manufacturing hub by 2030. Fruitful completion and timely commissioning of GEPs is anticipated to significantly drive economic transformation by enhancing electricity grid reliability, balancing, and supply diversity; GEPs provide a strategic source of least-cost power generation due to their high availability factor (95% and above), renewability and sustainability benefits [27, 44, 68]. Nevertheless, the local situation is not desirable because the mainstream media and oversight institutions recently highlighted cases of idle drilling equipment, IPP governance wrangles, disputed high-value contracts, exorbitant electricity tariffs, delayed start-up and commissioning of power plants, and project-community conflicts, among other contests [26, 27]. Also, a paltry 9.5% of the country's 10,000 MW plus potential has been exploited over four decades; average electricity prices are higher than regional peers inhibiting Kenya's competitiveness and growth potential; and delayed implementation of energy sector reforms to eliminate monopolistic practices by the power utility company has impeded competitive electricity pricing [28]. Accordingly, undertaking a scientific investigation into this undesirable situation provides an objective basis for fasttracking transformative institutional, policy, legislative and regulatory reforms.

Although financing and delivery of GEPs have been documented in more than twenty (20) countries globally, a critique by recent empirical studies confirmed the existence of opportunities for additional research on the subject matter [37,

40, 51, 56]. For instance, none of these scholars attempted to examine the joint relationship between the PPP financing structure and the completion of GEPs particularly in the SSA region; most of the studies were designed as longitudinal and relied on either qualitative or quantitative data obtained from documented project case studies from 1990 to 2018, before COVID-19 epidemic; and they did not integrate the public choice, agency, dynamic capability and systems theoretical lens. Contextual focus plays a significant role in the development of geothermal energy in places such as Switzerland [23]. The current study covers 48 diverse licensed projects in Kenya, providing a more national outlook on the role of PPP models in geothermal deployment, whereas previous research restricted its interrogation to a single project, Olkaria III [48].

### 1.3. Scope of the Current Research

The current study addresses the foregoing research and knowledge gaps by answering the following questions: “What is the relationship between PPP financing structure, government support, delivery capability, and completion of GEPs in Kenya; and what are the implications for geothermal energy development in the Sub-Sahara African context?”. Anchored on the public choice theory, the study also benefits from agency, dynamic capability, and systems theories to comprehensively address the research problem and answer the primary research questions. The study encompasses all GEPs licensed by EPRA as of 30<sup>th</sup> June 2023. It focuses on energy development rather than operational phases, utilizing a mixed-methods approach to data collection and analysis. The hypothesis posits that jointly, the PPP financing structure, government support, and delivery capability significantly affect GEP completion. Subsequent sections outline the literature review discussions, methodology, main findings, results and implications, and conclude with recommendations and areas for further research.

## 2. Literature Review

### 2.1. Geothermal Energy Development

Following the 1990s drought-related challenges, Kenya adopted PPPs for geothermal development, collaborating with numerous Development Financing Institutions (DFIs) through the Independent Power Producer (IPP) model. The Sessional Paper No. 4 on Energy restructured the sector's institutional framework, while subsequent policy reforms included the establishment of a National PPP framework, Feed-in-Tariff revisions and new regulations for renewable energy projects [19, 51]. Despite PPPs' potential to leverage private sector resources and promote innovation [60, 79], these projects face financing, delivery and completion challenges including inadequate public-private collaboration and budget overruns [26, 27, 36]. The existing literature reveals significant gaps in understanding the African geothermal development space, as

previous studies examine individual success factors but neglect their synergistic relationships [61, 75]. Previous studies offer policy insights but primarily analyze contexts differing from African realities or focus predominantly on developed and emerging markets, whereas this study investigates how PPP financing structure, government support, and delivery capability collectively affect geothermal project completion outcomes in Kenya [53, 76, 80, 83].

### 2.2. The PPP Financing Structure

The concept of PPP financing structure is founded on legally binding long-term agreements between public and private sector players about procurement, financing and implementation of a specified public infrastructure program or project [78, 79]. Ideally, such a structure for geothermal projects is outlined in a joint development agreement between key project parties. A good project financing structure should meet immediate funding requirements and guarantee the project's completion, long-term health and sustainability [21]. Unlike the concept of capital structure which is limited to debt and equity aspects, a PPP financing structure encompasses a blend of distinct sources availed in varying dimensions, amounts, terms and conditions; equity from government and private corporations, commercial loans from private lenders at market interest rates, concessional loans from DFIs at low interest rates, hybrid or mezzanine finance from a group of development banks, and grants from government and or development partners. The inherent merits and demerits of each financing source have been discussed comprehensively [45]. This study is limited to non-recourse project financing; it does not cover internal funds generated or earned during project implementation or operation. African project financing faces distinct problems including less capital market access and higher perceived country risk [49]. The influence of financing structures on different phenomena has been measured against availability, accessibility, debt-equity ratio, and equity-investment ratio [63]. For PPP projects with durations of 20 or more years, experts recommend using dynamic measures, especially affordability and internal rate of return, while this study specifically measures the sub-variables of availability, accessibility, affordability, and amounts [80, 82].

### 2.3. Government Support Measures

The concept of government support has been demystified under four categories: direct, indirect, financial intermediaries, and project development funds. The Government Support Measures Policy of Kenya defines government support as encompassing all institutional, legislative, policy and regulatory measures offered to project developers by government ministries, departments, agencies and counties [28]. These varied forms of government interventions may accelerate or slow the real influence of the PPP financing structure on project completion [41, 65]. This study interrogates institu-

tional mandates, PPP framework, tariff policy, Power Purchase Agreement (PPA), and connection guidelines due to their specific relevance to the study themes. East African governments have modified support mechanisms in geothermal development under a constrained fiscal space, with the sub-variables being measured in terms of relevance, effectiveness, and cost efficiency [38, 75].

## 2.4. Delivery Capability of Project Developers

The application of the delivery concept in construction and project management practices has only recently been demonstrated, despite being widely referenced in customer service and education training perspectives [39]. The concept of capability has been defined from different viewpoints in social sciences; for example, program and project delivery capability [8, 9, 32, 64], corporate and environmental governance [52, 77], risk management [47, 69], systems and resource-based view [2, 23], and strategic management [3, 4]. These different schools of thought indicate that the analysis of delivery capability is unique to the sector under review. In this case, developers refer to the private and state-owned entities responsible for PPP project procurement, financing, execution and operation. The definitions by IPA and PMI apply in this case; it comprises project governance, innovation, contract management, and benefits management. These qualities have been measured using the Agree-Disagree 5-point Likert scale [11, 13, 70].

## 2.5. Project Completion

Project completion reflects the systems approach to lifecycle management [14, 67]. Going by the public choice theory doctrines, the public investors are motivated to pursue the project completion since they are keen on risk transfer, cost recovery, value for money, utility volume or demand traffic, loan repayment schedule, lower utility charges, sustainability and ultimate development impact. On the other hand, private investors are motivated by risk transfer, transaction costs, return on investment, internal rate of return, interest cover, loan repayment schedule, and business integrity [42]. In most cases, complex PPP projects face multiple financing, delivery and completion challenges that require specialized capabilities and government support. From a multi-disciplinary standpoint, the timely completion of GEPs ought to address the agency problem faced by principals (public agencies) and their agents (IPPs). Project completion has been previously analyzed and measured using generic outcome indicators for scope, schedule, budget, quality, team and stakeholder satisfaction [46]. The construction of geothermal energy projects in this study has been assessed using more sector-specific technical, financial, social, and environmental metrics, while previous research identified distinct motivations between public and private investors and highlighted particular difficulties in land rights and community

engagement in Africa [42, 54].

## 2.6. Summary of Literature Gaps

Current research gaps include a limited focus on geothermal energy compared to other renewables [66, 84], predominant attention on developed nations [73], and insufficient examination of factor interdependencies [61]. While studies have examined the socio-economic consequences of renewable energy projects in Latin America, empirical evidence specific to African geothermal development remains sparse [27]. There was a lack of context-specific analysis where most studies focused on developed and emerging economies, often overlooking the specific challenges and opportunities in SSA countries [6, 7, 64]. Many existing studies relied heavily on secondary data, often collected from longitudinal case studies with limited timeframes, which may not fully capture the snapshot complexities of contemporary geothermal energy projects in SSA [20, 81]. This paper addresses the gaps highlighted above by focusing on geothermal energy development in Kenya, offering empirical insights into the joint influence of PPP financing structures, government support, and delivery capabilities on geothermal project completion outcomes. It conducts a cross-sectional census survey of all geothermal energy development projects licensed in Kenya; this study employs mixed methods to collect and analyze both quantitative and qualitative data, attaining a holistic investigation into the research problem; and thereby providing more current and comprehensive perspectives on the subject matter.

## 3. Theoretical Framework

This study is anchored in a comprehensive theoretical framework that integrates public choice, agency, dynamic capability, and systems theories. The integrated approach aims to expound how the predictor factors interact to influence project completion outcomes, highlighting the multifaceted nature of GEP implementation in a developing country setting.

*The public choice theory* developed through the work of economists like James Buchanan and Gordon Tullock, emphasizes that individuals in the political sphere primarily act based on self-interest [1, 17]. This perspective is crucial for understanding the motivations of project parties such as government officials, private sector partners, and community advocates, who are involved in the geothermal project development process. This theory illuminates how government policies and incentives are often shaped by the interests of influential stakeholders and political dynamics. Understanding these motivations is essential for evaluating the effectiveness of government support and the role of PPPs in facilitating GEP financing and renewable energy project completion.

*The agency theory* examines the relationships between principals and agents in situations where interests diverge [24, 34].



This theory is particularly relevant to geothermal energy projects, as it addresses potential conflicts that could arise among public and private parties during the project life cycle. Analyzing this interaction allows for a better understanding of how agency problems, such as the misalignment of goals and performance measurement challenges, affect project completion. The agency principles help explore governance support measures that could mitigate these issues, ensuring public and private partners act in the best interests of all key stakeholders.

*The dynamic capability theory* focuses on an organization's capacity to integrate, build, and adjust internal and external competencies to aptly respond to evolving environments [72]. This theory provides insights into why organizations should adapt to the complex and volatile nature of geothermal energy markets, regulatory landscapes, and technological innovations; this study investigated how the organization agility of GEP developers influences their delivery capabilities hence explaining changes in PPP financing structure and or project completion outcomes. This perspective was essential for understanding how public and private developers leveraged their dynamic capabilities to respond effectively to challenges and seize opportunities within the geothermal energy sector.

*The systems theory* posits that organizations (projects) must be understood as part of a larger ecosystem, comprising various interdependent components and stakeholders [18]. This theory facilitates a holistic understanding of how PPP financing arrangements, government policies, developer capabilities, development sector participation, and socio-environmental factors interact and shape project completion outcomes. This multifaceted approach allows for an in-depth analysis of the synergy among these factors, leading to practical recommendations on their joint influence on GEP completion outcomes.

## 4. Materials and Methods

### 4.1. Research Philosophy and Design

This study combines elements of positivism and pragmatism, acknowledging the importance of both objective and subjective realities in social science research. It adopted a mixed-methods research design to enable the collection and analysis of both quantitative and qualitative data. A descriptive cross-sectional survey was used to collect quantitative data from primary respondents for descriptive and inferential statistical analysis. Key informant interviews with secondary respondents were conducted to gather qualitative insights on the study themes. An ordinal scale of agreement enabled the collection of snapshot data at a single point in time, reducing susceptibility to external factors. To mitigate the limitations associated with cross-sectional surveys, data collection instruments were piloted, study intent was communicated to participants, and anonymity was ensured for all respondents.

### 4.2. Unit of Analysis and Census Survey

The unit of analysis comprised geothermal energy development projects licensed in Kenya as of 30th June 2023. A census of forty-eight (48) target projects was undertaken. The collection of project-specific quantitative data targeted 96 primary respondents made up of project managers from private developers (IPPs) and project implementation team leaders from state agencies. Additionally, 19 secondary respondents (directors) from relevant public, private, development, research, and academic organizations were targeted to provide key informant insights.

### 4.3. Data Collection

A multifaceted approach was applied where a structured questionnaire was the anchor data collection instrument. The questionnaire was carefully designed to elicit detailed responses from the primary respondents about the project background and key themes of the study. A 5-point Agree-Disagree (A-D) Likert scale was utilized to rank and assess the categorical responses. Besides, a Key Informant Interview (KII) guide was used to gather supplementary qualitative data from the secondary respondents. Also, an observation checklist was employed to systematically document the physical completion status of geothermal energy projects during site visits. Secondary data was gathered through an in-depth analysis of relevant literature and internet content. Peer review of the data collection instruments was done and high research ethical standards were observed.

### 4.4. Reliability and Validity

A pilot study on a PPP wind power project in Kenya was performed. The pilot results verified the reliability of the data collection instruments using Cronbach's alpha with a benchmark of 0.9 for excellence and 0.5 for unacceptable reliability, evaluated question accuracy through a Content Validation Index (CVI), and established face validity through consultation with subject matter experts. Four main diagnostic tests were performed to validate assumptions about the validity of the regression model and provide confidence in interpreting the results of the analysis: Variance Inflation Factor (VIF) test on the assumption of no significant multicollinearity; Normality test on the dataset's symmetry; graphical (P-Plots and histograms) and statistical (Kolmogorov-Smirnov and Shapiro-Wilk) techniques; Durbin-Watson (DW) test on the presence of autocorrelation; and Breusch-Pagan-Godfrey test on homoscedasticity. All the diagnostic test results were within the prescribed ranges.

### 4.5. Descriptive and Inferential Statistical Analysis

Descriptive statistical analysis tools were used to summa-

size, describe data sets and present results in tables and bar charts for better interpretation. Correlation and linear regression models were used to analyze inferential statistics. An integrated multiple linear regression analysis model was used to predict the joint influence of PPP financing structure, government support, and delivery capability on the completion of GEPs. The model was expressed as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + E$$

Where:

Y is the dependent variable, completion of geothermal energy development projects in Kenya;  $\beta_0$  is the intercept;  $X_1$ ,  $X_2$ , and  $X_3$  are the metrics of the predictor variables, PPP financing structure (PF), government support, and delivery capability;  $\beta_1$ ,  $\beta_2$ , and  $\beta_3$  are coefficients for the three predictor variables; and  $E$  is the error term.

To establish the overall robustness and significance of the joint influence of the three variables, an adjusted  $R^2$  was calculated at a 95% confidence level. If the adjusted  $R^2$  for the joint influence was greater than the sum of the individual  $R^2$  values for each variable, then the hypothesis was accepted, indicating that the joint influence was statistically significant [29].

#### 4.6. Qualitative Analysis and Data Triangulation

Qualitative responses gathered from KIIs were subjected to content reduction and thematic analysis tools. The main outputs of this analysis are frequency distributions, measures of central tendency (mean, mode), and measures of spread in the form of standard deviation and Coefficient of Variation (CV). The Chi-square test or cross-tabulation was done to determine the influence of government support on the PPP financing structure, delivery capability and completion of GEPs. To enhance the credibility of quantitative data analysis outcomes, a thematic data triangulation strategy was deployed to derive additional depth from qualitative data analysis results. In case of divergence between the two data sets, contrary qualitative perspectives were considered as additional factor (s) on the respective phenomenon. Further, glaring contradictions or inconsistencies arising from data triangulation constituted areas recommended for further research [10].

### 5. Results

The overall response rate was 82%. Studies suggest that response rates above 50% or 60% are considered adequate for most academic research [11]. High response rates are supported by assertions that they enhance data reliability. In this context, correlation and multiple regression analyses yield statistical evidence of various thematic relationships, while qualitative insights provide a rich contextual understanding, including descriptions of root causes and suggested solutions to the problem [16].

#### 5.1. Project Profiles

The power generation and plant development projects commanded 32% of the study focus, followed by steam gathering systems (19%), field development/exploration (17%), plant start-up (10%), operation and maintenance (9%), power evacuation/transmission (6%), plant upgrade/refurbishment (4%), and heating solutions (3%). A majority of the project budgets ranged from US\$100 million to US\$500 million, with a few outliers on the lower and higher ends of the spectrum (average US\$150 million). The predominant project implementation period ranged from 37 to 48 months (36%); others recorded 49-60 months (26%), 25-36 months (21%), 12-24 months (8%), and over 60 months (9%). This diversity in projects highlights the need for project-specific considerations on PPP financing options, government support needs and delivery capability development.

#### 5.2. Project Completion Status

About 52% of ongoing projects were reported to be on course, suggesting a positive outlook for the geothermal sector growth in Kenya. Another 28% were substantially complete, indicating that there is room to enhance efficiency and support to increase this percentage. In comparison, countries with more mature geothermal industries in North and South America, Asia, Nordic and Oceania countries, exhibit higher completion statistics due to more established government support mechanisms and regulatory frameworks. Approximately 19% had been delayed, highlighting significant challenges in the local geothermal project lifecycle. The delays were attributed to several factors, including IPP governance issues, financial constraints, funds flow delays, technical difficulties, regulatory hurdles, litigation and environmental non-compliance. Energy infrastructure projects in developing countries usually face delays, where financial and regulatory environments often pose substantial hurdles [78]. A paltry 1% had stalled, due to critical path implementation bottlenecks largely occasioned by severe funding shortages, insoluble technical issues, ethical issues or litigation. Large-scale infrastructure projects often stall where unforeseen risks or shifts in economic and political landscapes impact progress [22].

#### 5.3. The PPP Financing Structure

On average, a quarter of the project budgets were financed through government equity (25%), indicating a strong public sector commitment to de-risk especially in the vital early phases of geothermal development. Government grants accounted for only 1%, suggesting a preference for equity participation over direct subsidies. Private sector equity matched commercial loans (20%), collectively accounting for 40% of the financing; this substantial private involvement demonstrates investor confidence in the sector and demonstrates the attractiveness of geothermal projects. However, minimal market-interest loans were borrowed from the local commercial

banks. A combination of commercial loans (20%) and concessional loans (15%), translating to 35%, highlights the preference for both affordable and accessible debt financing options. Development partner grants contributed 15%, indicating strong international support for Kenya's geothermal ambitions. Hybrid/mezzanine finance, at 4%, shows some appetite for more complex financial instruments with the potential to bridge the inherent limitations of traditional equity and debt financing products. These findings illustrate the adoption of a balanced PPP financing approach to geothermal development in Kenya [51]. Analysts have observed a global shift towards market-based support mechanisms for renewable energy investments. Additionally, international cooperation has been emphasized as a crucial factor in advancing renewable energy in developing countries like Ghana. For instance, Ghana's collaboration with organizations such as IRENA has provided technical expertise and financial support, facilitating the country's transition to sustainable energy sources [12, 62].

#### 5.4. The Interplay Between Predictor Variables and Geothermal Project Completion

Table 1 and Table 2 indicate the outputs of correlation and

linear regression analysis.

**Table 1.** Model Summary and ANOVA Results.

Statistic	Value	Additional Information
R	0.814	Strong correlation
R <sup>2</sup>	0.663	66.3% variance explained
Adjusted R <sup>2</sup>	0.652	Robust after adjustment
Standard Error	0.40224	Reasonable prediction accuracy
F-statistic	59.004	Highly significant
Significance	0.000	p < 0.001
Regression SS	28.639	df = 3
Residual SS	14.562	df = 90
Total SS	43.201	df = 93

Source: Orlando et al. (2024)

**Table 2.** Variable Coefficients and Significance.

Variable	Coefficient	Std. Error	Beta	t-value	Sign.
Constant	0.243	0.364	-	1.669	0.021
Delivery Capability	0.607	0.091	0.555	6.682	0.000***
PPP Financing Structure	0.400	0.109	0.303	3.681	0.000***
Government Support	0.260	0.124	0.240	2.690	0.042*

Significance levels: \*\*\* p < 0.001, \* p < 0.05

Source: Orlando et al. (2024)

The regression model demonstrated strong explanatory power, with R<sup>2</sup> = .663 (adjusted R<sup>2</sup> = .652), indicating that the three independent variables collectively explain 66.3% of the variance in project completion outcomes. The model's statistical significance was confirmed by an F-statistic of 59.004 (p < .001), with a total regression sum of squares of 28.639 against a residual of 14.562, indicating a strong model fit.

Among the three variables, delivery capability emerged as the strongest predictor ( $\beta = .607$ , p < .001), followed by PPP financing structure ( $\beta = .400$ , p < .001), and government support ( $\beta = .260$ , p = .042). These coefficients reveal a hierarchical influence pattern while maintaining statistical significance for all variables. The strong statistical influence of delivery capability ( $\beta = .607$ ) resonates with the informants' emphasis on specialized technical expertise in geothermal development. Key stakeholders consistently identified technical competence in geothermal exploration and development

as fundamental to project PPP financing and completion. This encompasses resource assessment accuracy, plant design expertise, drilling management, and environmental impact mitigation.

The significant coefficient for PPP financing structure ( $\beta = .400$ ) corresponds with informants' detailed insights into optimal financing arrangements. The qualitative data analysis revealed a preferred financing mix: private equity (30-45%), commercial loans (30-45%), concessional loans and grants from DFIs (15-25%), and government contributions (equity and grants) (5-15%). While informants noted that this structure might extend initial negotiation periods, they emphasized its contribution to long-term cost-effectiveness and project sustainability. The need to address prolonged delays in development partner procurement and direct payment approvals/ no objection) was accentuated.

Although showing the smallest coefficient ( $\beta = .260$ ),

government support's statistical significance aligns with informants' recognition of its foundational role; government support measures create the enabling environment through regulatory frameworks, power purchase agreements, tax incentives, and streamlined permitting processes. Informants noted that while bureaucratic inefficiencies sometimes hamper effectiveness, government support remains crucial for better project completion outcomes.

### 5.5. Strong Explanatory Power of the Statistical Model

The statistical model's strong explanatory power ( $R^2 = .663$ ;  $F = 59.004$ ) supports informants' observations about the interconnected nature of these factors. Qualitative data also revealed a complex web of statements where government support shapes PPP financing structures, which in turn affects delivery capability. The robustness of the statistical model implies that expected project completion outcomes are attainable through the interaction of the three variables. The predictive power of the model, with an adjusted  $R^2$  of .652, highlights the value of integrated approaches in project financing, execution and control. The remaining minor influence (.337) may be explained by other factors identified for further research. Qualitative insights further illuminate how diverse factors work together to address GEP implementation issues.

## 6. Discussion of the Findings and Implications

### 6.1. Unlocking GEP Completion Bottlenecks

Despite the significant number of Geothermal Energy Development Projects (GEPs) rated as on-course (52%), another 19% were delayed due to systemic issues that need to be addressed to align with best practices observed in countries with high renewable energy project success rates (Baker et al., 2019). Although the minority stalled projects (1%) is a positive indicator, it is still not desirable under the systems theory given their huge aggregated investment value. Comparatively, stalling can be more common in some large-scale infrastructure projects in other sectors due to complex interdependencies and greater risk exposure [78]. Addressing these delays requires targeted remedial actions guided by the Synergistic Model presented in Figure 1. For example, minimizing the risk of stalling requires robust risk management strategies, sector-specific government support and agile project management capabilities amongst project developers. The analysis justifies the need for enhanced policy frameworks to address delays and support project completion. Policies focused on streamlined regulatory processes, financial incentives, and risk mitigation can significantly improve project timelines and completion out-

comes. The analysis highlights the importance of robust project management practices; project managers should focus on adaptive strategies, risk assessment, and stakeholder engagement to mitigate delays and ensure projects remain on course. The variability in project completion statuses offers a rich field for further research; exploring the underlying causes of delays and stalling, as well as best practices for geothermal project management can provide additional insights for improving GEP completion outcomes.

### 6.2. Suitability of the PPP Financing Structures

A mix of government equity and grants, private equity, commercial and concessional loans, grants and hybrids indicates a balanced approach to structuring PPP financing for GEPs in Kenya. While commercial loans are easier to access, concessional loans and grants from DFIs can help mitigate the high upfront costs and risks associated with geothermal projects [78, 79]. Comparing the country's PPP financing structure to global trends, both similarities and divergent aspects are observed. The strong government role (26% combined equity and grants) is higher than in many developed markets but aligns with trends in most emerging and developing economies. For instance, analysts have observed significant government participation in renewable energy financing in South Africa. For example, the South African government established the Renewable Energy Independent Power Producer Procurement Program (REIPPPP) in 2011, attracting over US \$16 billion in private-sector investment for 79 awarded projects totaling 5,243 MW of renewable energy capacity. Additionally, the government set up the Green Fund through the Department of Environmental Affairs to support the transition to a low-carbon, resource-efficient, and climate-resilient development path. These initiatives demonstrate government's active role in promoting and financing renewable energy projects [22]. The substantial private sector participation (40% equity and commercial loans) is encouraging and compares favourably with global averages. Analysts have reported a significant increase in private investments in renewable energy worldwide, with a notable surge in emerging markets [33, 44]. The significant contribution from development partners (15% grants) is characteristic of renewable energy project assistance in developing countries but higher than global averages. This reflects the strategic role of geothermal energy in Kenya's energy mix and global commitment to the 'Net Zero' transition goals. The use of concessional loans (15%) is consistent with practices in other developing countries; World Bank Group highlighted the importance of concessional finance in de-risking renewable energy investments in emerging and developing markets [78]. This structure appears well-suited to address the unique challenges of geothermal development in SSA, characterized by volatile market conditions, high upfront costs and exploration risks.



### 6.3. Synergistic Model for Geothermal Energy Development Project Completion

The main outcomes of this triangulated analysis are considerable for project management practice. First, it underlines the importance of balanced investments across all three variables, with top priority placed on establishing desired delivery skill sets and competencies. Second, it stresses the need to

structure PPP financing to ensure effective risk allocation facilitating optimal execution, completion and sustainability of GEPs. Lastly, it underlines the critical role of government support in building an enabling climate for private investments, development partner assistance, delivery capability enhancement and ultimately GEP completion. This emerging school of thought can be scientifically conceptualized into a synergistic model presented in Figure 1.

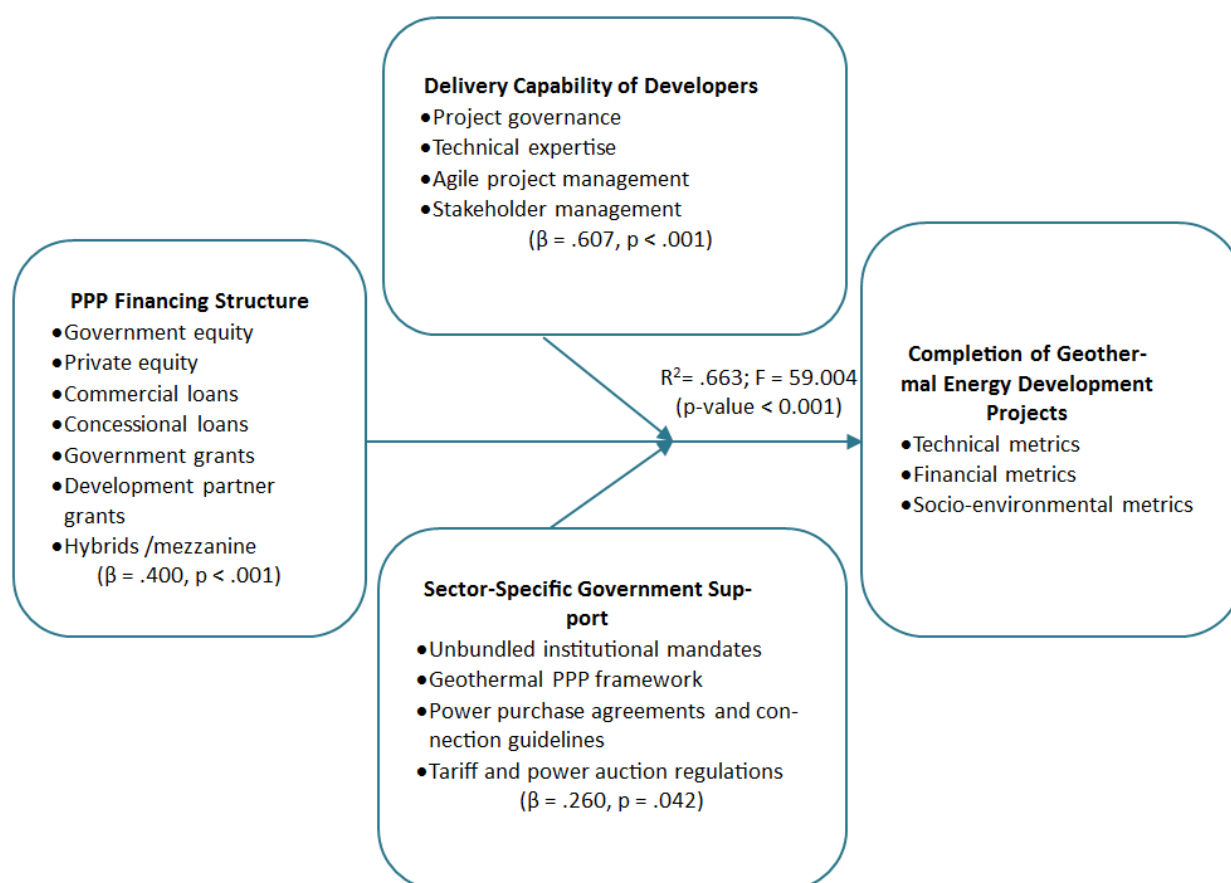


Figure 1. Synergistic Model for GEP Completion.

The delivery capability of developers encompasses the necessity for good project governance practices, suitable geothermal technologies and innovations, investments in local capacity development and technical training institutes, streamlining expatriate work permit processes, prioritizing value creation over completion of technical requirements, and implementation of policy frameworks for knowledge transfer from foreign collaborators. Field exploration, geothermal engineering, risk management, financial structuring and project management skills are desirable. Strengthening strategic partnerships and collaboration with global geothermal training institutes and leading geothermal development countries in developed and emerging geothermal economies is recommended. Moreover, the practice of agile project management methodology is essential. Deliberate integration of

contract and logistical management, environmental and social safeguards as well as project control systems is critical. Excellent stakeholder management includes clear governance structures, transparent decision-making processes, fostering regulatory compliance, effective benefit-sharing mechanisms and communication channels. The establishment of project management and delivery units, defined reporting and accountability frameworks, community engagement norms, and partner coordination systems are particularly essential for maintaining compliance and effective engagement among key project parties across the project lifetime.

The PPP financing structure is another crucial determinant of project completion, underscoring the significance of equitable risk distribution, wherein risks are fairly allocated between public and private stakeholders. Developing risk miti-

gation mechanisms and executing explicit risk management frameworks are crucial to managing uncertainty. In terms of financing, the report offers an optimal mix of funding: 30-45% private equity, 30-45% commercial loans, 15-25% concessional loans and grants from DFIs, 5-15% government equity and grants, and 5-10% hybrid/mezzanine finance. Embracing financial innovation will help bridge funding gaps by providing more flexible terms, especially for projects in high-risk phases like field exploration or early development. Also, embracing financial innovation through the uptake of hybrid /mezzanine finance, integration of green financing frameworks, and adoption of project bundling strategies, can attract and diversify the funding basket. The GEP financial model features are equally crucial, such as funder conditions, risk allocation through proportionate funding sources, proper debt-equity ratios, and flexible refinancing alternatives.

*Sector-specific government support* plays a substantial effect on geothermal project completion, underlining the importance of targeted government interventions, particularly in the areas of; institutional quality (unbundled institutional mandates), conflict resolution mechanisms, regulatory framework strengthening, investment incentives, capacity building and resource allocation. The government needs to establish clear regulatory rules, shorten permitting processes, and create direct incentive systems to stimulate geothermal growth. More so, strengthening regulatory bodies, implementing effective coordination mechanisms, and improving monitoring and assessment systems to enhance sector institutional quality. Additionally, adequate conditional funding for feasibility studies, market development, predictable partial risk guarantee/ letter of comfort issuance procedures, investments in land acquisition and horizontal infrastructure development, and support for environmental and social impact compliances are important. Financial assistance such as partial risk guarantee programs and tax incentives, financial intermediaries/special project funds, and incentivizing local commercial bank lending are also important. Governments are encouraged to also give technical support, including establishing funds for research and development, training programs, and technical assistance collaboration with global benchmarks to develop local capability needed for effective geothermal project implementation.

*Completion of geothermal energy development projects* is assessed using a holistic approach that considers project-specific outcome indicators categorized under technical, financial and socio-environmental metrics. The model acknowledges that other site and project-specific factors, not covered under the current study, may account for the remaining minor influence (.337) on GEP completion. Depending on the geothermal project type, these metrics should include project timeline adherence (time lapsed), budget adherence (cost overruns), value for money, drilling success rate, installed versus planned capacity, socio-environmental compliance rates, stakeholder satisfaction index, carbon credit target achievement, corporate integrity, and litigation record,

among others.

## 6.4. Novel Contribution to Theory, Practice and Policy

This research not only deepens the existing academic understanding of geothermal energy development but also offers practical insights that can inform policy-making and project management in the geothermal energy sector, particularly in the context of developing countries like Kenya. Theoretically, it merges public choice, agency, and systems theoretical principles to produce a geothermal sector-specific Synergistic Model (Figure 1) which attempts to interrogate and suggest solutions to variations in GEP completion outcomes. This model extends current ideas to the African geothermal environment, bringing new insights and opening a window for further research on other factors constituting the remaining minor influence on GEP completion. Methodologically, the study presents thorough measurement frameworks for important variables and combines quantitative and qualitative methodologies to provide a more complete analysis of geothermal project dynamics. It also gives practical suggestions for strengthening delivery capabilities, identifying optimal financing structures, and building frameworks for reviewing government support mechanisms. This paper therefore contributes to the project management literature through its context-specific insights, providing empirical evidence from an African context [36].

The study makes transformative contributions to project management and PPP practice, by highlighting the synergistic relationship between PPP financing structure, government support, and delivery capability. Rather than examining these factors in isolation, a holistic approach is recommended, recognizing the interconnectedness and dynamic interplay of these elements. This perspective moves beyond a silo approach to project management and emphasizes the need for an integrated strategy that considers all these factors simultaneously. Hence, demonstrating the importance of this synergy, the study provides a more comprehensive framework for understanding and approaching geothermal energy development project challenges, particularly in developing countries. Finally, the study offers contextual contributions by giving a detailed understanding of the project-specific constraints and possibilities faced by geothermal energy development projects in the SSA region, presenting context-specific solutions that can inform targeted government policy formulation; support geothermal sector growth; stimulate private sector participation; scale up development partner assistance; increase completion rates and value creation of GEPs.

## 7. Conclusions

This study investigated the relationship between PPP financing structure, government support, delivery capability and completion of Geothermal Energy Development Projects

(GEPs) in Kenya. The study effectively achieved its objectives, contributing to a deeper understanding of the complex dynamics influencing geothermal energy project completion in Kenya and the SSA region in general.

### **7.1. Diversity in GEP Profiles and Completion Statuses Necessitate Targeted Interventions**

The study determined the project profiles and completion status of GEPs licensed in Kenya as of 30<sup>th</sup> June 2023. The observed diversity in GEP profiles (types, budgets, implementation periods) highlights the need for targeted PPP financing sources, government support measures and project delivery capability. This finding underscores the heterogeneous nature of geothermal projects, potentially influenced by site-specific geological conditions, technological sophistication, or variations in project scale, schedule, scope, budgets and risk profiles. This implies that each project category is unique and hence requires specific interventions. While 52% of the projects were on course and 28% were substantially complete, on average, 1 out of 5 (20%) geothermal energy development projects in Kenya had delayed completion with a paltry 1% stalled; this aggregate 21% proportion is higher than the global best practices in developed and emerging economies. More targeted interventions from the government, project developers, financiers and development partners are therefore required to remedy this undesirable situation.

### **7.2. The PPP Financing Structure, Government Support and Delivery Capability Have a Significant Joint Effect on GEP Completion**

The substantial explanatory power (66.3%) of their joint effect highlights the importance of these determinants in the completion of GEPs, coinciding with findings by other researchers [1, 15]. The delivery capability of developers had the strongest predictor influence on GEP completion. Technical expertise was established as a critical success factor, supporting the Dynamic Capability theory and verifying earlier research that underlines the relevance of technical skills in geothermal exploration and development, particularly within the African context [30, 50, 72]. The PPP financing structure was determined as the second most influential factor; this aligns with key concepts of the Agency Theory and reinforces prior research on the success of PPPs in infrastructure projects [34, 61, 74]. This conclusion suggests that well-structured PPP arrangements promote project completion, financial risk distribution requires careful attention, balanced stakeholder interests support project completion, and innovative financing mechanisms add to project viability. Government support comes third; it ought to generate an enabling environment for suitable project financing choices, encourage private-sector participation, decrease regulatory barriers, and enhance project credibility and completion outcomes. This finding promotes the Public Choice theory (Buchanan & Tullock, 2003)

and supports recent research on policies in renewable energy development [27, 75].

### **7.3. Enhanced Delivery Capability and Sector-Specific Government Support Measures Improve GEP Completion**

Recognizing that strong technical expertise within project organizations [31], coupled with value optimization, agile project management practices and effective stakeholder engagement, are crucial for navigating complex technical challenges and ensuring efficient execution of geothermal energy projects. Government support plays a critical catalytic role in the selection of PPP financing sources, and delivery capability development, and slows or accelerates project completion outcomes [65]. There is a need to continuously evaluate effectiveness and improve government support measures, including addressing concerns around bureaucracy and inefficiency and engaging development partners to streamline approval processes. It is imperative to promote and incentivize the local commercial banks to increase lending for GEPs. A balanced mix of funding sources, clear risk-sharing mechanisms, and streamlined negotiation processes are essential to attract diverse investors and mitigate potential risks, ultimately contributing to better project completion outcomes.

### **7.4. An Integrated Approach Is Ideal**

The study also demonstrates that delivery capability, PPP financing structure, and government support do not work in isolation; rather, they exhibit considerable synergistic effects on GEP completion. This interaction suggests that the aggregate effect of these factors surpasses their isolated influence, with each variable mutually increasing the effectiveness of the others. A weakness in one area can be partially compensated by strengths in others, showing that ideal project outcomes require balanced growth in all three areas. This assertion supports the Systems Theory, which demonstrates the interconnectedness of the three variables, and validates the importance of an integrated approach to GEP project management [18]. The study also integrates four major theoretical frameworks (public choice, dynamic capability, agency, and systems) in the context of geothermal energy development, providing a novel theoretical synthesis that extends existing frameworks to the African renewable energy development space.

### **7.5. A Synergistic Model Is Recommended for Validation**

A structured implementation approach focusing on three key areas is recommended for validation in other countries with almost similar contexts as Kenya. First, delivery capability enhancement is the primary focus, requiring prioritization of project governance, technical expertise and techno-

logical innovations including artificial intelligence, Agile project management practices, value optimization and appropriate stakeholder management strategies. Second, a diversified and balanced PPP financing structure comprising suggested proportions of government equity and grants, private sector equity, commercial loans, concessional loans, development partner grants, hybrid/mezzanine and other innovative financing sources. Emphasis should be on optimizing context-appropriate financing mix, balanced risk allocation mechanisms, effective stakeholder interest integration, and partner coordination. Third, continuous assessment of sector-specific government support needs, streamlined regulatory processes, targeted incentive structures, and improved coordination mechanisms are vital. Increased private sector participation, project efficiency improvements, and local capability strengthening, can promote economic completion outcomes. Socio-environmental completion outcomes can be enhanced through effective stakeholder management, environmental and social safeguards, local employment creation, and community development initiatives. The findings and recommendations have broader implications for sector policy, PPP financing, and project and strategic management fields.

## 7.6. Limitations and Areas for Further Research

The study's scope was limited to a specific population of licensed GEPs in Kenya. This focused approach, while allowing for an in-depth examination of the SSA context, may restrict the generalizability of the findings to other regions. By employing a cross-sectional design, the research was unable to examine how the relationships between PPP financing structure, government support, delivery capability, and project completion outcomes might evolve over a long period. These limitations, while not diminishing the value of the study's findings, highlight the need for further research in this area. Future studies could address these limitations by expanding the geographical scope, employing longitudinal designs to capture changes over time, and probing specific dimensions of each variable to enhance the robustness and generalizability of the results. The synergistic model should be validated in another SSA country or region.

## Abbreviations

CV	Coefficient of Variation
CG	Completion of Geothermal Energy Development Projects in Kenya
CVI	Content Validation Index
DC	Delivery Capability
DFI	Development Financing Institutions
DW	Durbin-Watson
EARV	The East African Rift Valley
EPRA	Energy Projects Regulatory Authority
GEP	Geothermal Energy Development Projects

GS	Government Support
GoK	Government of Kenya
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
KII	Key Informant Interviews
PPP	Public-Private Partnership
PPA	Power Purchase Agreement
PMI	Project Management Institute
SSA	Sub-Saharan Africa
VIF	Variance Inflation Factor
UNEP	United Nations Environmental Program
WBG	World Bank Group

## Author Contributions

**Sitati Olando:** Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft, Writing – review & editing

**Mary Nyawira Mwenda:** Supervision, Validation

**Reuben Wambua Kikwatha:** Supervision, Validation

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## Conflicts of Interest

The authors declare no conflicts of interest.

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