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Advancing Energy Infrastructure in Madagascar: Exploring the Potential of Public-Private Partnerships

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***Abstract*— Madagascar's energy sector relies heavily on biomass, mainly wood, for heating and cooking, with low per capita energy consumption. Despite challenges, the country aims for ambitious electricity access and cleaner energy goals, favoring Public-Private Partnerships (PPPs). This study examines PPP potential for energy infrastructure development through a multicriteria analysis, comparing PPPs with other models. Results highlight PPPs' strong financial viability, cost-effectiveness, and ability to attract private sector resources for rapid expansion. Strategic suggestions focus on optimizing PPP benefits while ensuring transparency. This research informs Madagascar's policymakers and stakeholders, showcasing PPPs as a key solution for sustainable growth and improved electricity access.**

***Keywords*— Madagascar, energy sector, electricity access, PPP, multicriteria analysis, sustainability.**

I. INTRODUCTION

The energy sector in Madagascar mirrors developing nations, relying heavily on biomass, mainly wood, for cooking and heating. Biomass constituted 99.2% of primary energy production and 89.3% of domestic consumption in 2020. Per capita energy usage is notably low, reaching 17% of the global average and 49% of the African average in 2019. Electricity usage represents only 2.4% of total energy, primarily from fossil fuels (57.7%) and renewables (42.3%).

Despite these challenges, Madagascar aims for ambitious electricity access and energy transition goals. The New Electricity Policy (NEP 2015-2030) targets 70% household electricity and an 80% renewable energy mix by 2030, requiring effective mechanisms.

Public-Private Partnerships (PPPs) are favored for achieving these objectives. PPPs combine public sector stability with private sector efficiency, innovation, and expertise. This article explores PPP potential for Madagascar's energy infrastructure development. We'll analyze PPPs, Public Owner Management (POM), and Engineering, Procurement, Construction, and Financing (EPC+F) through multicriteria evaluation.

This analysis will uncover method advantages and challenges, spotlighting PPPs as catalysts for Madagascar's energy transition. Tailored recommendations will be offered for successful PPP implementation, fostering sustainable growth, universal electricity access, and environmental preservation.

II. STUDY OBJECTIVES

The primary objective of this study is to assess the potential and advantages of Public-Private Partnerships (PPPs) as a model for acquiring energy infrastructure in Madagascar. To achieve this overarching goal, several specific sub-objectives have been defined:

A. Multicriteria Analysis of Acquisition Modes

Conduct a comprehensive and comparative analysis of various methods for acquiring energy infrastructure, including PPPs, Public Owner Management (POM), and Engineering, Procurement, Construction, and Financing (EPC+F). This analysis will consider key criteria such as environmental sustainability, financial viability, accessibility and equity, transparency and governance, implementation speed, and innovation capability.

B. Assessment of PPP Potential in Madagascar:

Examine Madagascar's specific conditions, encompassing budget constraints, available resources, and the country's energy needs. Evaluate how PPPs can leverage private sector financial and technical resources effectively for the development and management of energy infrastructure.

C. Identification of PPP Advantages:

Highlight the specific advantages of PPPs compared to other acquisition methods. Analyze how PPPs can offer superior risk management, advanced technical expertise, project flexibility, and enhanced transparency in decision-making processes.

D. Strategic Recommendations:

Based on the results of the multicriteria analysis and the assessment of PPP potential in Madagascar, formulate specific strategic recommendations for the successful implementation of PPPs in energy infrastructure development. These recommendations aim to maximize PPP benefits while

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mitigating potential risks and addressing the country's energy needs.

E. Contribution to Energy Transition:

Identify how PPPs can significantly contribute to Madagascar's energy transition by promoting the use of renewable and sustainable energy sources. Evaluate how PPPs can assist in achieving the goals of the New Electricity Policy (NEP 2015-2030) concerning electricity access and the energy mix.

By achieving these objectives, this study aims to provide crucial insights for policymakers, investors, international organizations, and stakeholders in Madagascar's energy sector. The findings of this study can serve as a solid foundation for making informed decisions regarding the adoption of PPPs as a preferred acquisition model for energy infrastructure development, thereby contributing to the improvement of Malagasy citizens' lives and the sustainable economic growth of the country.

III. Research Methodology

In pursuit of the objectives outlined in this study, we have adopted a rigorous and comprehensive research methodology, employing weighted multicriteria analysis to evaluate different methods of acquiring energy infrastructure in Madagascar. The essential steps we have followed are as follows:

A. Literature Review

A thorough exploration of relevant literature was conducted to comprehend Madagascar's energy sector, the country's energy challenges, infrastructure acquisition methods, and experiences of PPPs in similar geographical contexts. This review aided in identifying the key criteria necessary for our weighted multicriteria analysis.

B. Data Collection

Primary and secondary data were collected to inform our assessment. Primary data were obtained through interviews with energy sector experts, government officials, private sector representatives, and civil society stakeholders. Secondary data were sourced from government reports, academic publications, case studies, and official energy statistics concerning Madagascar.

C. Criteria Identification and Weighting

Based on literature review outcomes and expert consultations, key criteria for evaluating energy infrastructure acquisition methods were identified. These criteria encompassed cost, environmental sustainability, social impact, implementation complexity, and return on investment (ROI). By assigning weights to each criterion based on their relative importance, we established a scale of 1 to 5 to reflect their respective decision-making weights.

D. Weighted Multicriteria Analysis

We evaluated each energy infrastructure acquisition method against the identified criteria, assigning scores on a scale of 1 to 10. These scores were weighted using the weights allocated to each criterion, enabling the calculation of weighted scores for each method.

E. Assessment of PPP Potential

To assess the potential of PPPs in Madagascar, we examined the country's specifics, including energy needs, budgetary constraints, legislation, and capacity to mobilize private sector resources. We drew lessons from successful PPP experiences in other developing countries to inform our analysis.

F. Identification of PPP Advantages

By comparing the weighted scores of different acquisition methods, we identified the specific advantages of PPPs, including their ability to mobilize private resources, distribute risks, leverage private sector technical expertise, and promote transparent and efficient project management.

G. Formulation of Strategic Recommendations

Building on the results of our weighted multicriteria analysis and the assessment of PPP potential, we formulated strategic recommendations aimed at maximizing PPP benefits in the development of energy infrastructure in Madagascar, while ensuring the country's financial and environmental sustainability.

H. Addressing Limitations

We acknowledged the limitations of our study, such as data collection constraints and inherent uncertainties in weighted multicriteria analysis. Nevertheless, we sought to mitigate these limitations by employing robust research methods and consulting sector experts.

By adopting this rigorous research methodology grounded in weighted multicriteria analysis and utilizing robust data, we have delivered reliable and relevant outcomes to support policymakers and stakeholders in their endeavors to effectively develop energy infrastructure in Madagascar. This will contribute to a successful energy transition, improved electricity access, and sustainable economic growth for the country.

IV. Data Collection and Analysis : Multicriteria Analysis Method

A. Data Collection

Data collection involved primary (PDS) and secondary sources (SDS) to ensure reliability and relevance. PDS included interviews with energy experts (IEE), government representatives (GR), private sector actors (PSA), and civil society organizations (CSO) in Madagascar. These interviews provided insights into energy acquisition practices, challenges, and development opportunities. SDS comprised official reports (OR), case studies (CS), academic publications (AP), and statistics from national (NS) and international organizations (IOS).

B. Evaluation Criteria for Multicriteria Analysis

The ten key criteria selected for evaluating energy infrastructure acquisition methods were as follows:

1) Total Project Cost: Assessing estimated overall costs for each acquisition method, considering Madagascar's financial capabilities.

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2) Financial Viability: Analyzing the economic feasibility of each method, considering initial costs, operating and maintenance expenses, as well as financing flows and returns on investment.

3) Accessibility and Equity: Comparing each method's ability to provide equitable electricity access across the country, especially for urban and rural areas.

4) Transparency and Governance: Evaluating governance quality and associated transparency for each method, emphasizing stakeholder participation and decision-making responsibility.

5) Implementation Speed : Comparing the implementation speed of each method, accounting for the time required to realize energy infrastructure.

6) Innovation Capability: Assessing the potential for integrating innovative technologies and sustainable solutions into each acquisition method.

7) Experience and Technical Expertise: Measuring the experience and technical expertise required for successful implementation of each method.

8) Private Sector Involvement: Evaluating private sector involvement in terms of financing, management, and responsibilities for each method.

9) Risk Management: Analyzing risk distribution between the public and private sectors for each method.

10) Value for Money: Evaluating the efficiency of each method in terms of value added compared to costs incurred.

C. Multicriteria Analysis

Using the weighted multicriteria analysis method, we evaluated each energy infrastructure acquisition method by assigning weighted scores (WS) on a scale of 1 to 5 for each criterion. These scores were determined in collaboration with energy sector experts in Madagascar to reflect the country's decision-making priorities.

By summing the weighted scores for each criterion, we calculated an overall score (OS) for each acquisition method, representing its relative performance. The formula for calculating the overall score (OS) is given by:

$$OS = \frac{\sum_{i=1}^{n} WS_i}{n} \quad (1)$$

Where:

n is the total number of criteria.

WS_i represents the weighted score for the *i*-th criterion.

This approach enabled a balanced comparison of the advantages and disadvantages of each method.

Through this rigorous multicriteria analysis methodology, we obtained comprehensive results. These findings provided an overarching perspective on the strengths and weaknesses of PPPs, POM, and EPC+F for energy infrastructure development in Madagascar.

Based on these results, we formulated strategic recommendations in favor of PPPs, which notably stood out for its financial viability and favorable value-for-money proposition. These informed recommendations aim to guide policymakers and stakeholders in selecting the most suitable acquisition method for the efficient and sustainable development of the country's energy infrastructure. After the text edit has been completed, the paper is ready for the template. Duplicate the template file by using the Save As command, and use the naming convention prescribed by your conference for the name of your paper. In this newly created file, highlight all of the contents and import your prepared text file. You are now ready to style your paper; use the scroll down window on the left of the MS Word Formatting toolbar.

V. Results of the Multicriteria Analysis

Following the application of the multicriteria analysis methodology and the assignment of weighted scores to each energy infrastructure acquisition method, we have obtained significant results that shed light on the decisions favoring Public-Private Partnerships (PPPs) for energy infrastructure development in Madagascar.

A. Weighted Scores for Each Acquisition Method

Below are the weighted scores for each acquisition method, based on the multicriteria analysis:

TABLE I. Weighted Scores

Criteria	*Public-Private Partnership (PPP)*	*Owner Management (POM)*	*Engineering, Procurement, Construction, and Financing (EPC+F)*
Total Project Cost	4.0/5	2.5/5	3.5/5
Financial Viability	4.5/5	3.0/5	4.0/5
Accessibility and Equity	4.0/5	3.0/5	4.0/5
Transparency and Governance	4.5/5	3.0/5	4.0/5
Implementation Speed	3.5/5	2.0/5	3.0/5
Innovation Capability	4.0/5	3.0/5	3.5/5
Experience and Technical Expertise	3.5/5	2.5/5	4.0/5
Private Sector Involvement	4.5/5	3.0/5	4.0/5
Risk Management	3.0/5	2.5/5	3.5/5
Value for Money (Quality-Cost Ratio)	4.5/5	2.5/5	3.5/5
Total Weighted Score	**40.0/50**	**26.0/50**	**37.0/50**

B. Interpretation of Results

The obtained results clearly demonstrate that the Public-Private Partnership (PPP) is the most relevant method for energy infrastructure acquisition in Madagascar, achieving the highest weighted score among the three evaluated methods. This outcome aligns with the objectives set forth in the country's New Electricity Policy (NPE 2015-2030), which aims to provide electricity to 70% of households and achieve an 80% renewable energy mix by 2030.

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C. *Analysis of Results by Criterion*

Total Project Cost: PPP achieved a score of 4 out of 5, showcasing its capability to mobilize private resources for financing a significant portion of the project, thereby alleviating the financial burden on the state.

Financial Viability: PPP garnered a high score of 4.5 out of 5, indicating its economic feasibility through private sector involvement in financing and project management.

Accessibility and Equity: PPP obtained a high score of 4 out of 5, highlighting its capacity to provide equitable access to electricity across the country.

Transparency and Governance: PPP received a high score of 4.5 out of 5, underscoring the quality of governance and transparency in decision-making processes associated with this method.

Implementation Speed: PPP scored 3.5 out of 5, demonstrating a relatively swift implementation speed, though additional efforts could be considered to expedite the process further.

Innovation Capability: PPP received a high score of 4 out of 5, indicating its ability to integrate innovative technologies for sustainable energy development.

Experience and Technical Expertise: PPP achieved a score of 3.5 out of 5, demonstrating that the required technical expertise is available in both the private and public sectors.

Private Sector Involvement: PPP garnered a high score of 4.5 out of 5, highlighting strong private sector engagement.

Risk Management: PPP scored 3 out of 5, reflecting its risk-sharing approach between the public and private sectors.

Value for Money (Quality-Cost Ratio): PPP achieved a high score of 4.5 out of 5, indicating its effectiveness in terms of value added relative to costs.

D. *Total Weighted Score:*

The total weighted score for PPP is 40.0 out of 50, underscoring its prominence as the preferred method for energy infrastructure development.

VI. Discussion and Implications of Results

The results of the multicriteria analysis highlight the Public-Private Partnership (PPP) as the most suitable method for energy infrastructure acquisition in Madagascar. PPP offers significant advantages in terms of financial viability, equitable access to electricity, transparency, innovation, and value for money. The strong involvement of the private sector enables the mobilization of additional financial and technical resources, thereby alleviating the financial burden on the state and accelerating the development of energy infrastructure.

However, it is essential to emphasize that the success of PPP hinges on effective implementation, rigorous risk management, and continuous monitoring to ensure the achievement of set objectives. Robust and transparent governance is also crucial to ensure equitable participation of all stakeholders and safeguard Madagascar's interests in this partnership.

The findings of this study provide a solid foundation to inform decision-makers and relevant stakeholders in Madagascar's energy sector. Strategic recommendations can be formulated to promote the use of PPP as an effective means of developing sustainable energy infrastructure, thereby enhancing access to electricity for all citizens and fostering the country's economic and social development.

VII. CONCLUSION

In conclusion, this study unequivocally establishes Public-Private Partnership (PPP) as the optimal approach for energy infrastructure acquisition in Madagascar. The outcomes of the rigorous multicriteria analysis underscore the remarkable benefits of PPP encompassing financial soundness, impartial access, transparency, innovation, and cost-effectiveness. By harnessing private sector resources and risk-sharing, PPP uniquely positions itself to accelerate the imperative expansion of essential energy infrastructure, harmonizing with the nation's ambitious targets for electricity accessibility and sustainable energy transformation.

Nonetheless, the triumphant execution of PPP necessitates meticulous pre-planning, vigilant oversight, and a continuous cycle of evaluation. The symbiotic partnership between the public and private sectors remains pivotal in cultivating an environment conducive to the successful realization of PPP initiatives.

Looking ahead, future research should focus on long-term PPP sustainability, fostering innovation, and cross-country comparisons. Madagascar's embrace of PPP promises sustainable progress and an elevated quality of life. Through a comprehensive longitudinal study, insights into the enduring efficacy and evolution of PPP implementation in the energy sector can be gained. Moreover, exploration of innovative technologies within the framework of PPP can optimize energy infrastructure, advancing Madagascar's journey towards a more resilient and eco-friendly energy paradigm. Additionally, conducting cross-country comparisons will yield valuable lessons by contrasting PPP initiatives' experiences and outcomes across diverse global contexts. This will refine Madagascar's PPP approach and enrich its endeavors, propelling the nation further along its trajectory of sustainable growth and prosperity.

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