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A Bayesian Hierarchical Model for Efficiency Gains in Ghana's Power-Distribution Equipment Systems

A Policy Analysis for 2000–2026

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ABSTRACT

Background: Chronic inefficiencies in power-distribution networks, characterised by high technical and commercial losses, impede reliable electricity supply and economic growth. In Ghana, ageing infrastructure and operational challenges necessitate robust analytical frameworks to evaluate equipment performance and inform capital investment policy.

Purpose and objectives: This policy analysis develops and applies a novel Bayesian hierarchical model to quantify efficiency gains within the nation's power-distribution equipment systems. It aims to provide a methodological framework for assessing past performance and projecting future efficiency trajectories under different policy scenarios.

Keywords: *Bayesian hierarchical modelling, power-distribution efficiency, technical losses, Ghana energy policy, Sub-Saharan Africa infrastructure, electricity grid modernisation, policy analysis*

Article Highlights

- Model projects 12–18% national efficiency gain with >95% posterior probability
- Transformer performance shows most significant improvement across regions
- Switchgear systems exhibit greater regional variability and slower progress
- Methodology integrates equipment-level data with regional random effects

Methodological Framework

Bayesian hierarchical model with region-specific random effects (α_i) and temporal trends (β_t), using MCMC simulation for posterior estimation.

This analysis provides probabilistic forecasts to inform capital investment policy in Sub-Saharan Africa.