JCARM
Journal of Contemporary Academic Research and Methodologies

An Online Peer Reviewed / Refereed Journal
Volume 1 | Issue 6 | July 2026
ISSN: 3139-7247 (Online)
Website: www.journal.jcarm.in

Review Article

The Impact of Energy Efficiency Technologies on Productivity in FMCG Manufacturing Plants in Sub-Saharan Africa

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Article No: 034 | **Accepted**: 08 July 2026 | **Published**:10 August 2026

Abstract: Energy efficiency has become a critical strategic priority for large manufacturing plants globally due to rising energy costs, carbon reduction targets, and increased sustainability expectations. This qualitative study examines energy efficiency strategies in large manufacturing plants, focusing particularly on the FMCG (Fast-Moving Consumer Goods) sector in Sub-Saharan Africa. Semi-structured interviews were conducted with plant managers, energy officers, and machine operators to explore awareness, adoption patterns, operational barriers, and perceived cost–benefit dynamics of energy efficiency initiatives. Findings show that high-consumption processes such as HVAC(Heat ventilation, and air conditioning), high-pressure compressors, process heating, and motor systems offer the highest potential for savings. However, barriers such as capital constraints, lack of technical expertise, and inconsistent government incentives limit adoption. The study proposes a layered framework of operational, behavioral, technological, and managerial strategies for sustainable energy optimization.

Keywords: Energy Efficiency, FMCG Manufacturing, Sub-Saharan Africa, Industrial Sustainability, Qualitative Research.

1. INTRODUCTION

Energy consumption in manufacturing facilities has increased significantly due to expanding industrial output and automation trends. Large manufacturing plants, especially FMCG (Fast-Moving Consumer Goods) factories, contain energy-intensive operations such as continuous production lines, refrigeration systems, compressed air systems, and thermal processing. Energy efficiency has therefore become a strategic priority for cost reduction, sustainability compliance, and carbon footprint reduction.

 https://doi.org/10.5281/zenodo.21860340

This research adopts a qualitative approach to uncover real-world practices, perceptions, and constraints faced by manufacturing stakeholders in deploying energy-efficiency strategies.

2. LITERATURE REVIEW

Energy efficiency has become a defining factor in the operational sustainability and competitiveness of industrial and manufacturing plants in developing regions, particularly across Sub-Saharan Africa. Rising energy costs, unreliable power supply, and pressure to reduce carbon emissions have led industries to adopt new operational strategies and technologies (IEA, 2022; World Bank, 2020). This literature review synthesizes findings from academic, institutional, and policy-based sources to understand the qualitative dimensions of energy efficiency adoption, challenges, and organizational responses in industrial sectors. Guided by the thematic analysis framework by Braun and Clarke (2006), the literature is reviewed around three emergent themes: technology adoption, energy management practices, and institutional/operational constraints.

2.1 Theoretical and Conceptual Foundation

Energy efficiency in manufacturing is grounded in the broader sustainability agenda, which emphasizes optimized resource usage, waste reduction, circularity, and performance improvement (Bocken, 2017). UNIDO (201U) articulates the central role of industrial energy management systems (EnMS) in enhancing productivity and competitiveness, while IEA (2022; 2023) highlights energy efficiency as the “first fuel,” essential for achieving global net-zero targets.

The industrial sector in Africa aligns with these global frameworks but faces region-specific constraints such as infrastructural gaps, financing limitations, and low technology absorption rates (World Bank, 2020; Amadi, 2021).

2.2 Motor and Drive Systems

Motor systems account for a significant share of manufacturing electricity consumption. The U.S. Department of Energy (2021) and its 2022 updated guide emphasize high-efficiency motors, variable-frequency drives (VFDs), and motor right-sizing as major opportunities for energy savings. Adeyemi and Olanrewaju (201U) provide empirical evidence from Nigeria’s beverage industry showing that VFD adoption in compressors reduces power consumption and increases equipment lifespan. Their qualitative findings also reveal organizational hesitancy in adopting new technologies, usually due to cost considerations and limited technical expertise.

2.3 HVAC and Thermal Systems

Industrial heating, ventilation, and cooling systems present substantial energy-saving opportunities. Arora (2018) details various HVAC optimization strategies, including demand-controlled ventilation, heat-recovery systems, and improved insulation designs. Complementing this, the Carbon Trust (2020) emphasizes maintenance optimization and steam-system retrofits as low-cost opportunities for significant operational gains.

2.4 Cross-Cutting Efficiency Technologies

Broader frameworks highlight the increasing role of automation, digital monitoring, and predictive analytics. Abdulrahman (2020) notes that African manufacturing systems that integrate automation and energy-monitoring tools tend to outperform traditional systems. This aligns with global trends identified by LBNL (2020), which stresses industrial analytics, system-wide energy modeling, and strategic operational decision-making.

2.5 Energy Audits and Assessment Practices

Energy audits remain a cornerstone of qualitative and operational energy management. Obeng (2020), in a study of FMCG factories in Ghana, reports that systematic energy audits reveal hidden inefficiencies such as compressed-air leakage, oversized machinery, and avoidable idle-time losses. These findings support recommendations from the Carbon Trust (2021), which emphasize continuous monitoring and staff-oriented behavioral change programs.

2.6 Organizational Systems, Culture, and Capacity

UNIDO (201U) describes structured energy management systems as mechanisms that integrate technical interventions with managerial processes. Their toolkit highlights leadership engagement, staff capacity building, and cross-departmental communication as necessary for sustained improvement. Similarly, the U.S. Department of Energy (2022) identifies employee training, performance tracking, and structured audit programs as essential components of industrial energy management.

2.7 Global and Regional Trends in Industrial Energy Efficiency

IEA (2023) underscores the growing global shift toward advanced efficiency technologies such as digital energy management systems, heat pumps, and industrial electrification. However, adoption rates in developing economies lag behind due to capital and policy constraints. The World Bank (2020) similarly notes that industrial competitiveness in developing regions depends increasingly on energy performance, forcing companies to seek innovative solutions despite structural barriers.

UNIDO (201U) stresses that capacity building, policy support, and regional energy partnerships can accelerate industrial transformation in Africa. These recommendations echo global best practices from the U.S. Department of Energy (2022) and Carbon Trust (2021), which emphasize integrated management systems and long-term efficiency planning.

2.8 Financial and Economic Limitations

Amadi (2021) identifies financial constraints as one of the most persistent barriers in Sub-Saharan industries. High upfront capital costs for efficient technologies often discourage adoption despite long-term payback benefits. This aligns with the World Bank (2020), which highlights limited access to credit, poor capital markets, and macroeconomic instability as conditions that hinder industrial efficiency investments.

3. PROBLEM STATEMENT

Despite the availability of advanced technologies, many manufacturing plants still operate below optimal energy efficiency levels due to inadequate monitoring, outdated machinery, or poor organizational practices.

4. RESEARCH BOUNDARIES

4.1 Functional Area

Energy Management, Industrial Operations, and Sustainability Management.

4.2 Focus / Topic

Energy Efficiency, Operational Optimization, Industrial Sustainability.

4.3 Geographical Area

Nigeria and Ghana (Sub-Saharan Africa Industrial Belt).

4.4 Sample / Population

Plant managers, energy officers, maintenance engineers, and machine operators.

4.5 Study Area / Context

Large-scale manufacturing in the FMCG (Fast-Moving Consumer Goods) sector, including beverage plants, flour mills, packaging factories, and household consumable production plants.

5. RESEARCH OBJECTIVE

i. To explore the types of energy-consuming equipment and processes in large manufacturing plants.
ii. To identify current energy efficiency strategies adopted across FMCG (Fast-Moving Consumer Goods) facilities.
iii. To analyze perceived benefits and barriers to energy efficiency adoption.
iv. To propose a realistic strategy framework tailored to large plants in Sub-Saharan Africa. To develop a nice and suitable energy efficiency framework.
v. To develop a cost-benefit analysis.
vi. To develop an implementation roadmap
vii. Investigate barriers to adequate implementation of the energy efficiency strategy

6. METHODOLOGY

6.1 Research Design

A phenomenological qualitative design was used to capture the lived experiences of plant personnel.

6.2 Data Collection

- 18 Semi-structured interviews
- G Focus group discussions
- On-site walk-through energy observations using plant equipment logs
- Review of energy reports and utility bills

6.3 Data Analysis

- Thematic coding
- Pattern mapping
- Comparative content analysis

- **7. FINDINGS AND DISCUSSION**

7.1 Major Energy Consumers in Large FMCG (Fast-Moving Consumer Goods) Plants

Table 1: Key Energy-Consuming Systems

Energy Intensity (High/Med/Low)	Stakeholder Perception	Notes
High	"Always running; it wastes energy if leaking"	Up to 30% of the plant electricity load
High	"Critical for product stability	Heavy load in beverage & food plants
High	"Runs 24/7 in large plants"	Major target for VFD (Variable frequency drives) installation

High	“Fuel cost growing yearly”	Huge opportunity for heat recovery
Mediu m	“We switched to LED recently”	Quick, low-cost savings
Low	“Not significant”	<5% of total consumption

Illustrative Calculation: Energy Savings From VFD (Variable frequency drives) Installation Assumptions based on a typical FMCG (Fast-Moving Consumer Goods) compressor:

- Rated motor: 200 kW
- Avg. load reduction with VFD: 25%
- Daily operation: 20 hours
- Electricity cost: $0.15 per kWh

Energy Saved Per Day

Reduction = 200 kW × 25% = 50 kW

Daily Savings = 50 kW × 20 hours = 1,000 kWh/day Cost Savings Per Year

Annual Cost Savings = 1,000 kWh/day × 3G5 × $0.15

= $54,750 per year

7.3 Interview Themes

Theme 1: High Awareness but Low Implementation

Managers understood energy efficiency but lacked financial backing and technical expertise. Theme 2: Behavioral Waste Is Significant

Common examples:

- Idle conveyor systems
- Compressed air leaks
- Worn steam traps
- Machines left “ON” during lunch breaks

Theme 3: Maintenance Gaps Increase Energy Waste

Plants with poor preventive maintenance experienced 12–30% higher energy bills.

Discussion

The qualitative findings indicate that plants adopting integrated strategies combining technology, organizational behavior, and digital monitoring achieve the most substantial returns. The calculations illustrate how even incremental improvements [e.g., VFD (Variable frequency drives) deployment] can produce large annual savings.

Organizational culture was found to be equally important as technological investment.

8. STRATEGY FRAMEWORK FOR ENERGY EFFICIENCY

8.1 Operational Strategies

- Leak detection in compressed air systems
- Steam trap inspection
- Use of automatic shut-off controls
- Heat recovery in boiler systems

8.2 Technological Strategies

- Variable Frequency Drives (VFDs)
- Smart sensors and IoT monitoring
- LED retrofits with intelligent control
- High-efficiency motors (IE3/IE4)
- Waste-to-energy integration

8.3 Behavioral Strategies

- Energy awareness training
- Staff performance incentives
- Energy dashboards and visual signage

8.4 Managerial Strategies

- Appointing dedicated energy managers
- Establishing monthly energy audit cycles
- Linking energy KPIs to departmental performance
- Green procurement policies

9. TABULATION OF QUALITATIVE PERSPECTIVE

Table 2: Stakeholder Perspectives on Major Barriers

Group	**Barrier Reported**	**Frequency**	**Illustrative Quote**
Plant Managers	High capital cost	Very high	“We know the solution; we can’t afford it.”

Maintenance Engineers	Technical expertise gap	High	“We need more training on VFD (Variable frequency drives)tuning.”
Operators	Lack of automation	Medium	“Manual systems waste energy.”
Energy Officers	Poor data availability	High	“Meters are outdated or inaccurate.”

10. ROI (Return on Investment) Computation for LED Replacement (Example)

- Existing Fluorescent Load: 50 kW
- LED retrofitted load: 18 kW
- Reduction: 32 kW
- Operating hours: 1G hours/day
- Electricity cost: $0.15/kWh
- Cost of LED retrofit: $18,000

Energy Saved Per Year

32 kW × 1G × 3G5 = 18G,000 kWh/year

Cost Savings

18G,000 × $0.15 = $27,U00/year

Payback Period

$18,000 / $27,000 ≈ 0.G5 years (8 months)

10. CONCLUSION

Energy efficiency in large manufacturing plants requires a multi-dimensional approach. Large manufacturing plants in Sub-Saharan Africa face significant energy challenges but also possess substantial savings potential. Low-cost strategies (behavioral + operational) can immediately reduce waste, while advanced technologies such as VFDs (Variable frequency drives), high-efficiency motors, and IoT monitoring systems deliver long-term savings. A combination of data-driven insights, strategic leadership, technological upgrades, proper maintenance culture, and consistent training is essential for sustainable progress and offers the highest potential for energy reduction

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References

1. Abdulrahman, A. (2020). Energy optimization in African manufacturing systems. *Journal of Industrial Engineering*.
2. Adeyemi, K., & Olanrewaju, M. (201U). Adoption of variable frequency drives in beverage industry compressors. *Energy Systems Review*, 12(3), 45–5U.
3. Amadi, S. (2021). Barriers to energy efficiency in Sub-Saharan industries. *African Journal of Engineering Management*, 8(1), 27–3U.
4. Arora, R. (2018). *Industrial HVAC efficiency practices*. International Energy Press.
5. Bocken, N. (2017). Sustainable manufacturing frameworks. *Journal of Cleaner Production*.
6. Carbon Trust (2020). *Energy-saving opportunities for boilers and steam systems*.
7. IEA (2022). *Energy Efficiency 2022: Global Outlook*.
8. Obeng, P. (2020). Energy audits in Ghanaian FMCG factories. *West African Journal of Applied Engineering*.
9. UNIDO (201U). *Industrial Energy Management Toolkit*.
10. U.S. Department of Energy (2021). *Motor System Efficiency Guidebook*.
11. World Bank (2020). *Industrial competitiveness and energy use in developing economies*.
12. Braun, V., & Clarke, V. (200G). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101.
13. International Energy Agency (IEA). (2023). *Energy Efficiency 2023 Report*.
14. U.S. Department of Energy. (2022). *Energy Efficiency Best Practices for Industrial Plants*.
15. Carbon Trust. (2021). *Manufacturing sector insights on energy management*.
16. Lawrence Berkeley National Laboratory. (2020). *Industrial Energy Analysis and Strategy*
