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FROM NON-TECHNICAL LOSSES TO FINANCIAL SUSTAINABILITY: A COMPREHENSIVE FRAMEWORK FOR ELECTRICITY THEFT RECOVERY IN NIGERIA

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ABSTRACT

Nigeria's electricity sector faces exceptionally high non-technical losses (NTLs), mainly due to electricity theft, which harms cash flow, discourages investment, and leads to poor service quality. This paper presents a comprehensive, Nigeria-specific theft-recovery framework that directly links the causes of NTLS to financial sustainability outcomes. The framework includes diagnostics that combine data governance, quantitative analytics, machine-learning detection, and stakeholder insights; diverse interventions such as technical solutions (like metering and AMI deployment), policy reforms (cost-reflective tariffs, enforcement, data standards), customer engagement programmes, and economic incentives (performance-based regulation and targeted rewards); a phased governance and implementation plan assigning roles to federal regulators, DisCos, and private actors; and monitoring indicators focused on revenue recovery, loss reduction, operating margins, and cash-flow stability. Case studies from high-loss environments inform design choices and support a pragmatic sequence of pilots and scaling efforts. Policy recommendations include coordinated subsidy reform, bankable mechanisms for cost recovery of loss-reduction investments, and transparent accountability structures to rebuild sector credibility. Overall, this framework offers a

practical path to reduce theft, stabilise utility finances, and improve access to reliable electricity.

KEYWORDS: Electricity theft; Non-technical losses; financial sustainability; Nigeria power sector; Advanced metering infrastructure; Performance-based regulation.

1. INTRODUCTION

Nigeria is recognised as having the highest level of electricity theft globally, a serious issue that results in approximately 34% of total electricity generated being lost, along with 79% of the electricity distributed by the monopoly utility not being billed to consumers (Obafemi, 2021). The widespread problem of electricity theft impacts all segments of society, but it disproportionately affects the poor, who represent a significant majority of those engaging in illegal connections. This rampant theft of electricity not only undermines the financial sustainability of the electricity sector but also increases illegal connections for critical services, including water supply. In fact, electricity theft accounts for the largest share of Non-Technical Losses (NTLs) impacting the Nigerian electricity sector. NTLs are defined explicitly as any electricity consumption that is either unaccounted for or not billed to any consumer. As a direct consequence of these issues, Nigeria consistently ranks among the world's highest NTL levels. (Hu et al., 2020)(N. Ofoegbu & E. Emengini, 2013)

2. The Problem of Electricity Theft in Nigeria

Electricity theft constitutes a substantial obstacle to improved power availability across Nigeria, inflicting direct economic losses estimated at 29 billion naira (over 63 million USD) monthly (Hu et al., 2020). Beyond the immediate revenue forfeiture, theft incurs additional operational costs. Supply losses necessitate proportional increases in generated energy, which in turn lead to higher equipment wear, fuel procurement costs, and other expenses. Low recoverable revenue hinders recovery of operating costs, generating fiscal deficits that constrain maintenance and investment. Persistent nationwide blackouts compel the use of illegal connections or the exploitation of billing flaws (Mbanjwa, 2017), aggravating supply losses and tariff collection challenges. Regulatory instruments for promoting and safeguarding investments in the nation’s electricity ecosystem remain to be established. Utility ownership cannot, under prevailing circumstances, improve the economic efficiency of electricity provision, jeopardising private-sector investments, sustainable development, and national advancement.

Unreliable service delivery in the electricity sector has greatly encouraged arbitrary and opportunistic involvement by various actors, ultimately stymying the much-needed commercial restructuring required for progress. The resultant rise in electricity theft includes a wide range of activities that detract from the billed supply, and these factors are distinguishable from conventional non-technical losses. Non-technical losses typically encompass a variety of phenomena such as faulty metering, errors in customer registration, and inconsistencies arising from transaction errors. A systematic, structured non-technical losses framework enables a comprehensive assessment of theft activities and facilitates identification of their prevalence and the factors that contribute to their occurrence. This approach also provides a pathway for re-engagement in the commercial sphere, aiming for a restorative progression that brings the electricity system closer to its historical performance criteria. By addressing these issues proactively, we can work towards a more reliable and efficient electricity sector. (Skaloumpakas et al.2024)

3. Conceptual Framework: From Non-Technical Losses to Financial Sustainability

Electricity theft in Nigeria accounts for over 50% of non-technical losses, possibly the highest globally. Addressing this is vital for economic sustainability and development. A framework to diagnose and address losses distinguishes between technical (physics-based) and non-technical (preventable) losses, and between financial losses resulting from non-technical losses. Collecting data on non-technical losses is crucial to reducing financial losses. Theft methods include meter bypass, tampering, fraud, incorrect billing, and illegal connections, all of which lead to revenue loss. Meter bypass causes a revenue shortfall; tampering may raise or lower bills, both reducing income; fraud involves false information to avoid payments; billing errors cause full-value losses; illegal connections under- or unbill loads, lowering revenue (Olanrele, 2025).

Analysis of the implications of non-technical losses for financial sustainability indicates that total revenue loss equals the quantity of electricity not billed multiplied by the unit price. In addition, when tariff structures convey signals to motivate demand reductions, non-technical losses reduce the effective price consumers face, thereby promoting excess demand. Financial sustainability in terms of cash position can also be substantially affected; non-technical losses, combined with energy theft, require greater generation capacity and, hence, higher capital expenditures before the utility can maintain positive cash flow. (Joaquim et al., 2017)

3.1. Definitions and Scope

Electricity theft, broadly defined as unauthorised use of electrical energy, is one of the most pervasive, preoccupying, and damaging challenges for contemporary power utilities (Mbanjwa, 2017). The problems stemming from electricity theft in Nigeria have been described as unprecedented and mind-boggling. Incidents of diverted electrical current, meter tampering, meter bypass, faulty meter readings, rebilling, billing anomalies, undelivered bills, and illegal electrical connections abound (Joaquim et al., 2017). As utilities' revenues decline significantly and the costs of generation, transmission, and distribution continue to rise, the issue of electricity theft undermines efforts to achieve sustainable national economic development. This situation hampers critical initiatives to create emergency jobs, particularly those essential for communities in need. To tackle this pressing concern, early detection and thorough analysis, alongside both quantitative and qualitative assessments of fraudulent activities, are imperative. These measures not only help identify the scope of the problem but also support the development of well-informed proposals for an effective intervention program. Furthermore, adopting a comprehensive diagnostic approach enables an in-depth evaluation of strategies to combat electricity theft, thereby enhancing the overall effectiveness of the measures implemented. (Ndulaka et al.2025)

3.2. Mechanisms of Theft and Losses

Electricity theft can take many forms, including physical tampering with meters and wiring to reduce or evade payment, fraudulent meter design, and payment evasion through alterations or omissions in the billing process (Hu et al., 2020). Physical tampering, such as bypassing the meter, connecting to distribution lines upstream of the meter, or diverting current illegally, is the most common method and can all be classified as unmetered energy theft. Although sophisticated, fraudulently designed meters exist, they are less common than other strategies. Alternative strategies that evade tariff payment without bypassing metering, and instead alter the invoice itself or affect the content delivered to metered users, also exist and can be characterised as complex methanisation (Joaquim et al., 2017).

3.3. Financial Implications for Utilities

The direct financial implications of electricity theft for utilities operating in Nigeria's privatised electricity market are significant, yet these implications are rarely quantitatively assessed. Electricity theft creates revenue leakage and has significant cash-flow impacts through postpaid consumption, requiring utility firms to finance customer debt before

revenue is collected. Measures to address theft in Nigeria could therefore improve the financial health of electricity utilities operating in privatised markets (Özay & Çakıt, 2025). Utilities experiencing significant revenue losses from theft are pressured to raise tariffs in order to cover shortfalls. The inevitable cross-subsidisation of unmetered customer classes pursuing postpaid consumption to non-consumers is generally incompatible with transparency and undermines further efforts to enhance financial performance. Higher tariffs also spark widespread customer unrest and are therefore undesirable for utilities financially dependent on redeploying cash and debt recovery (Gershon & Ezurum, 2017). Power purchase and operational expenditures may also increase in response to electricity theft, generating pressures on broader utility finances. These additional costs include outlays for purchasing and installing equipment to maintain illegal connections; developing protection against tampering; and expanding expenses across other segments of utility operations to maintain the prevailing level of service (N. Ofoegbu & E. Emengini, 2013).

4. Diagnostic Methodologies

Surveys of Nigerian utilities indicate that electricity theft is a preeminent challenge (Hu et al., 2020). Heavily implicated in the country's broad spectrum of non-technical losses, unaccounted-for, unmetered, and unpaid electricity theft behaviours include bypassing, tampering, and fraudulent transactions on meters, alongside illegal connections and billing errors (Joaquim et al., 2017). Loss rates of 50% or more are documented (Ikpe, 2020). The current leading-edge practices for diagnosing loss magnitudes across various systems rely on advanced quantitative models, which are instrumental for inferring leakage levels and extracting valuable insights into underlying theft mechanisms from consumption data. These sophisticated methodologies incorporate statistical, econometric, and stochastic modelling techniques, thereby systematically exposing irregularities through detailed regression analyses, comprehensive component breakdowns, and thorough scenario explorations. In addition to these quantitative approaches, qualitative analysis plays a crucial role in complementing the overall framework by effectively delineating the operational context. It also articulates specific channels through which theft occurs and aggregates diverse stakeholder perceptions, ensuring a well-rounded understanding of the components at play in loss magnitude assessment. This integrated approach ultimately enhances the ability to identify, analyse, and mitigate potential losses, thereby improving the efficacy of loss management strategies. (Goyal & Mukherjee, 2025)

4.1. Data Collection and Quality Assurance

Data collection constitutes a fundamental step in diagnosing non-technical losses. Defining the precise scope of these losses in the Nigerian context requires a comprehensive overview of available information sources and quality assurance methods. Utilities have also begun to recognise the importance of data governance in ensuring the integrity of data collection procedures and facilitating increased stakeholder engagement (Hu et al., 2020). The collection and verification of data from customers, bills, technical operations, and monitoring devices can help to inform loss-diagnostic efforts through various qualitative and quantitative modelling approaches (Joaquim et al., 2017). Every distribution network is composed of numerous nodes that play a crucial role, as these nodes are the points through which various monitoring devices efficiently communicate with a central data repository. This central repository acts as the hub for data collection and analysis. Utility staff members can directly enter all relevant and critical information into this central repository, ensuring a seamless flow of data. In recent years, stakeholder interfaces have increasingly been used to capture customer information directly. This approach significantly mitigates potential user resistance to installing smart meters, which are essential for modern utility management. Furthermore, such interfaces facilitate more effective bilateral information exchange, enabling a more interactive and responsive relationship between utility companies and their customers. (Rajaguru et al.2024)

4.2. Quantitative Assessment Models

Quantitative assessment models for non-technical losses use various approaches, including data clustering, pattern recognition, and statistical analysis. Techniques such as the optimal path forest have been applied for fast identification and consumer data clustering. Statistical analysis of energy loss factors can help quantify and understand loss patterns. Advanced methods such as machine learning, class imbalance strategies, and feature engineering are used to improve the detection of energy theft and malicious meters. Several studies emphasise the importance of data-driven models to enhance accuracy and efficiency in loss assessment (Joaquim et al., 2017). Electricity is a vital resource, and electricity theft causes significant economic losses and safety hazards. Traditional hardware-driven detection methods face limitations due to the need for expert knowledge, regional differences in tactics, and adaptability issues when thieves change strategies. Data-driven methodologies have been applied to improve detection, focusing on identifying non-technical losses such as electricity theft, which manifests as abnormal non-technical loss records. However, existing machine

learning approaches have struggled with the diversity and irregularity of electricity usage behaviours. To overcome these challenges, a comprehensive approach is proposed to recognise electricity theft by integrating information across micro, meso, and macro levels (Hu et al., 2020).

4.3. Qualitative Insights and Stakeholder Perspectives

The problem of electricity theft and non-technical losses in Nigeria has been intensely studied. Nonetheless, there remains a notable lack of relevant information and qualitative analysis of stakeholder perceptions and the incentives that shape interactions with electricity service providers. To enrich the diagnostic effort and strengthen the assessment of customer-related non-technical losses, the research process incorporated semi-structured interviews with diverse stakeholders at the Federal and state levels, as well as electric utility representatives and customers across several geographical locations. The interviews sought to understand the meanings, motivations, and consequences customers attach to their interactions with power systems and suppliers. (Sibiya & Ogudo, 2024)(Aniedu et al.2021)

The qualitative evidence gathered from these interviews is vital for further elucidating non-technical losses and developing a comprehensive understanding of the electricity theft phenomenon and the broader issues associated with the electricity market in Nigeria. Interviews were conducted with a range of stakeholders in Nigeria's electricity sector to better understand issues related to electricity theft and non-technical losses. Short, open-ended questions were used to gather the desired information, with interviewees self-selected. Many of the respondents were subsequently invited to participate in the study. The insights gained, although informal and largely anecdotal, shed light on the prevailing perceptions regarding the issues under study. The insights reveal that electricity theft is both a high-profile and stridently debated issue, particularly amongst the supply sector. Interviewees indicated that customers purposely bypass locks or tamper with various types of meters. Customers on prepaid metering systems were described as stealing electricity by reusing vouchers even after the usage had reached zero. Others were found to have acquired fake stickers with associated codes used for obtaining electricity. Numerous residential buildings serve as points of illegal connection to other facilities. Many occupants pay for electricity under the assumption that the service and product supplied represent government work and, as such, need not be compensated (Mbanjwa, 2017).

5. Strategic Interventions

Electricity theft recovery has become a pressing concern for the Nigerian power sector, demanding immediate and effective interventions. A comprehensive analysis identifies technical, policy, customer engagement, and economic pathways to systematically address the problem of electricity theft. Definitive strategies targeting non-technical losses first involve implementing an array of technical measures that strengthen the integrity of metering systems, enhance regulation of meter installations, foster adoption of advanced metering infrastructure, and facilitate real-time detection and reporting of outages. Active promotion of such measures equips utility firms to mitigate financial exposure while developing credible yet precise forensic diagnostics to ascertain the scale and causes of remaining losses. Pervasive reform of policy and regulatory frameworks emerges as another critical focal point. Sustained revenue recovery remains deeply enmeshed with the country's long-standing commitment to subsidising prices for vulnerable consumers. This situation obliges providers to implement increasingly meticulous procedures and stricter norms for metering policy, fraud protocols, data governance, and pricing for non-subsidised customers. Steps to recalibrate existing frameworks address the underlying economic rationale of such critical utility functions more directly.

Robust customer engagement and demand-side management initiatives constitute complementary solutions that facilitate a better understanding of service provision, regulations, rates, and practices across diverse clientele. Rounding out a menu of strategic measures, a set of economic instruments and incentives is introduced. These leverage tariff and governance structures to encourage both utility providers and grid users to adopt practices that contribute systemically to the overall improvement of electric service nationwide (N. Ofoegbu & E. Emengini, 2013; Hu et al., 2020; Joaquim et al., 2017).

5.1. Technical Measures for Loss Reduction

Electricity theft undermines economic growth, deters investments, and disrupts service. Alongside a poor electricity supply, Nigeria has contended with staggering non-technical losses specifically due to electricity theft, billing inefficiencies, and metering anomalies, which cripple providers. Theoretical analysis and case studies from emerging economies reveal that non-technical losses diminish the financial viability of distribution enterprises and impede access to investments needed to expand and rehabilitate supply capacity (Joaquim et al., 2017). Consequently, engagement in non-technical loss reduction, particularly the

recovery of theft losses, is vital to Nigeria's efforts to increase electricity supply and enhance economic growth (Hu et al., 2020). In this context, a comprehensive framework elucidates the preconditions and processes underlying the recovery of theft and non-technical losses. Crafted for the Nigerian electricity sector, the framework helps analyse the patterns and factors contributing to non-technical losses, including theft. The sequence focuses on the financial sustainability of distribution enterprises and the investment, service-delivery, and regulatory constraints that limit electricity supply, a challenge endemic to the Nigerian sector.

5.2. Policy and Regulatory Reforms in Customer Engagement and Demand Management

Strategic policy and regulatory interventions can significantly enhance the recovery of electricity theft in Nigeria. To stimulate much-needed financial inflows into the sector, tariff structures must be reformed to enable adequate cost recovery. At the same time, metering standards must be raised to curb fraudulent activities and improve billing accuracy (N. Ofoegbu & E. Emengini, 2013). The capacity of regulatory agencies to enforce laws and standards can be strengthened to enable compliance. At the same time, anti-fraud regulations should be put in place as a line of defence against illegal connections. To effectively manage the vast amount of data generated in the sector, privacy regulations are also essential. Human behaviour plays a pivotal role in shaping energy consumption patterns. Customers exhibit diverse preferences, needs, and readiness to engage with the electricity grid. Demand-side management and active customer engagement are essential to addressing non-technical losses, particularly electricity theft, as outlined in sections 3.2 and 3.3. In Nigeria, significant demand-side management opportunities exist and can be strategically leveraged within the theft recovery framework.

The incorporation of customer engagement methodologies can significantly mitigate the quantitative and qualitative dimensions of electricity theft, as discussed in sections 3.2 and 3.3. Enhancing customer awareness of theft-prevention measures, promoting the consequences of illegal consumption, fostering participation in fraud reporting, and offering incentives to reduce theft while ensuring community protection constitute viable engagement strategies. Establishing communication channels and forums to discuss rate structures, notification procedures, payment privileges, metering accuracy, and outage information further contributes to customer education.

5.3. Economic Instruments and Incentives

Economic instruments can complement technical measures and policy reforms to counter electricity theft. Utilities frequently impose penalties on customers suspected of tampering with meters or stealing power, but such penalties are often ineffective. Customers may pay the penalty while continuing to steal electricity. In addition to penalties, incentives for loss reduction can serve as effective instruments that promote the utility's financial sustainability. Performance-based regulation, in which utilities and customers share in the cost savings from reductions in technical and non-technical losses, encourages voluntary action at the customer level. Such arrangements can take various forms, including sliding-scale discounts on electricity bills for loss reduction, multi-year cost-sharing agreements based on defined targets to improve the utility's cash flow and expand connections to new customers, or other performance-based structures. Cost recovery arrangements that allow utilities to earn a reasonable return on investments aimed at reducing losses also create incentives for utilities to undertake such measures.

Drawing on the previous discussion of the financial implications of electricity theft, economic instruments and incentives aligned with the recovery of operating costs and cash flow emerge as priority areas for improving financial sustainability (Gershon & Ezurum, 2017). Non-technical losses from electricity theft undermine the utility's ability to perform routine functions, such as investment planning, maintenance, and energy conservation measures.

6. Governance and Implementation Pathways and Responsibilities of Institutions

In Nigeria, technical losses account for 21% and non-technical losses (mostly theft) for 43% of the electricity supplied, severely affecting the financial stability of supply companies (DisCos) and the sector (Gershon & Ezurum, 2017). In 2021, losses reached N1.87 trillion (US$4.5 billion). Recovering non-technical losses, especially theft losses, is vital to viable pricing and operations. The sector's governance involves multiple bodies: the FGN, NERC, TCN, NEMSA, the market operator, DisCos, and others. A coordinated approach is needed, with phased roles for each stakeholder. Electricity theft occurs through meter bypass, tampering, fraud, billing issues, and illegal connections, impacting various loss categories like supply, demand, metering, and commercial.

Electricity theft is prevalent in many countries, but Nigeria's situation is striking in scale and severity. According to official figures, the nation suffers non-technical losses equivalent to 40% of total metered consumption, three times the global average and the bulk of these losses is attributed to theft (N. Ofoegbu & E. Emengini, 2013). The soaring shortfall in cash collected is less readily quantifiable. However, estimates indicate a monthly financial impact of 167 billion Naira (0.46 billion USD) on Nigerian Electricity Supply Industry (NESI) revenue (Eniola Victor, 2017). Inadequate cash collection is a core factor undermining the financial sustainability required for power sector recovery. However, because of the nature of theft, its scale, diversity, and deep entrenchment, official investment in it is seen as a barrier; it warrants systematic analysis. National reform efforts, however, have failed to resolve the electricity crisis. Governance, regulation, commercialisation, and privatisation initiatives, along with multiple funding modalities, have not produced meaningful improvements. The limited analysis of the causes of intractable sector collapse, few detailed examinations of specific problems or partial solutions, and total absence of `theft' from discussions of the fundamental determinants of ongoing failure reflect poorly on current initiatives. Given the unprecedented scale of non-technical losses, an electricity theft recovery framework is warranted before discussing loss-reduction measures.

6.1. Phased Implementation Roadmap

Developing an implementation roadmap for electricity theft recovery in Nigeria involves strategic organisation into phases, each comprising complementary activities. These phases correspond to the length and depth of preventive efforts, as delineated in the preceding overview. The roadmap offers a critical tool to guide the design and sequence of interventions over the near- to medium-term. Roadmap proposals must remain adaptable, allowing for refinement in response to the evolving operating and political environment. In addition, a phased implementation pathway enables prioritising foundational diagnostics (data collection, aggregation, and exploratory analysis) and efficient incrementalism, as short-term, medium-term, and expansion measures complement pilot initiatives. The framework strongly emphasises pilot testing of new measures to minimise uncertainty and optimise design features, as addressable determinants of rollout choice. Towards that end, accompanying selection criteria govern both programme prioritisation and broader intervention choices (Joaquim et al., 2017). The roadmap's priority design gives prominence to technical (metering, supervision, outreach) and policy (tariffs, standards, outreach) measures, since these establish an expanded knowledge base, stimulate continued data

capitalisation, and improve understanding of remaining unaddressed loss factors. Electricity theft manifests through mechanisms as diverse as meter bypass, tampering, and fraud; each contributes to distinct non-technical-loss types. Consequently, Nigeria's utility environment and electricity-supply configuration provide a foundation for professors and research assistants to assess the focus of theft recovery.

6.2. Risk Management and Mitigation

Effective management and mitigation of electricity-theft-related risks are essential for utilities seeking to recover losses and achieve financial sustainability. The Nigerian electricity sector is characterised by governance, political economy, and corruption challenges, which complicate policy implementation through political and administrative channels (Salman, 2016). Consequently, awareness of electricity-theft risks and the development of management and mitigation measures constitute crucial preparatory actions prior to implementing theft-recovery interventions. Several prominent risks hinder the successful recovery of electricity theft. First, extensive delays in program implementation can lead to waning public information campaigns and stakeholder engagement (Joaquim et al., 2017). Second, the ability to estimate theft in monetary terms is constrained by data unavailability at the regulatory level and by a lack of confidence in data quality; if significant data gaps or biases that allow theft to continue go undetected, recovery efforts will be ineffective despite political commitment (Hu et al., 2020). Third, the political economy still poses a challenge; missing or faulty regulations about competition and unbundling raise questions about regulatory credibility, especially when anti-theft programs are launched. Fourth, data gaps adversely affect the development of behaviour-based models of theft, hampering the understanding of governance and regulatory implications. Lastly, bankability concerns arise due to perceived high-risk factors, including theft, which deter participation in market auctions. Together, these risks significantly hamper efforts to curb electricity theft in Nigeria.

7. Monitoring, Evaluation, and Accountability Indicators for Financial Sustainability

Indicators for financial sustainability include equipment availability, service quality, and reducing uncontrolled sales and consumption, monitored through numerical indicators and frameworks. Setting target values helps assess the impact of strategies. Different measurement methods and report formats suit various stakeholders, influenced by the monitoring body's preferences. Electricity theft and non-technical losses hinder utility

sustainability, especially in Nigeria, where these issues are severe. Combating theft requires addressing non-technical losses simultaneously to be effective.

Financial sustainability refers to a utility's capacity to cover operating costs, keep assets in good shape, and stay financially healthy without ongoing government aid (N. Ofoegbu & E. Emengini, 2013). Monitoring this is vital for companies aiming to attract private investment and enhance electricity services. Five indicators evaluate utilities' handling of non-technical losses, especially theft: revenue recovery rates measure confirmed metered sales, payment discipline, and meter infrastructure quality. Loss reduction rates indicate unaccounted energy, covering technical and non-technical losses. Operating margins show the difference between revenue and costs, considering loss escalation and sales to other providers. Cash-flow health gauges if energy sales cover cash-out expenses and unrecovered costs. These variables stem from Nigeria's regulatory framework, tariffs, operational efficiency, service quality, and competition (Hu et al., 2020). Using these indicators helps identify issues, raise awareness of losses and technical limits, clarify the relationship between theft and operational performance, and encourage transparent collaboration among operators and government (Joaquim et al., 2017).

7.1. Evaluation Frameworks and Reporting

The proper selection of evaluation frameworks guides the reporting of monitoring and evaluation results, ensuring clarity about the status of interventions addressing electricity theft. Given the complex economic environment in Nigeria, reporting formats should ensure adequate understanding of progress against multiple sustainability dimensions while avoiding the perception of a single failure indicator (Joaquim et al., 2017). Two distinct yet complementary frameworks serve to balance these considerations:

- **Evaluation for accountability** assesses the extent to which the overall recovery plan has been implemented, providing inputs for stakeholder dialogues about policy and regulatory reforms. The fundamental tenets of such evaluations comprise periodic audits of the planned and actual milestones achieved by the proposed interventions, supplemented by independent reviews that assess the reasons for variances against the implementation roadmap. Regular status reports documenting the overall situation support an action-oriented approach towards recovery.

- **Evaluation for learning** centres on the extent to which the recovery plan improves the financial and operational sustainability of Nigeria's electricity distribution sector, given its

foundational role in meeting national development objectives. Periodic assessments of a limited set of key performance indicators facilitate adaptive management and fine-tuning of planned recovery interventions, enabling early detection of potential avenues for further improvement or the emergence of unintended side effects (Eberhard et al., 2016).

7.3. Learning and Adaptation Mechanisms

The combined effects of electricity theft, meter tampering, illegal connections, inadequate service standards, and vandalism of power lines have impeded infrastructure development in Nigeria. Sub-national and local government levels often lack accurate records and information that are widely available at the federal government level. Nevertheless, the regulated activities of the Nigerian Electricity Regulatory Commission (NERC) suggest significant potential to finance infrastructure development, manage the national economy effectively, and improve investor confidence. The mechanisms by which transparency and accountability can improve service delivery and reduce the infrastructure deficit are illustrated through various initiatives undertaken by the Lagos State Government. (Adebayo et al.). Technical measures or losses are improperly conflated with non-technical losses or theft at the federal level. It is also important to distinguish between theft by the private sector and service compromise by power supply companies. Although the statistics emerging from the NERC portal appear suspect, they nevertheless conform to nationwide average estimates. A lower-bound economic analysis, for which data are not yet available, of the psychological, social, and financial costs associated with non-technical losses also points to the need for prompt action to promote financial sustainability. (Adebayo and Ainah, 2024)

To monitor progress and assess the impact of the proposed interventions on the financial sustainability of electricity utilities in Nigeria, a robust set of learn-and-adapt mechanisms ensures a continuous flow of relevant information within the sector. Reporting, verification, and validation aspects are crucial to maintain close oversight over these non-technical losses and ultimately to ensure electricity sector financial sustainability in Nigeria. (Joaquim et al., 2017)

8. Case Studies and Lessons Learned

Electricity theft is a pervasive problem that severely compromises the Nigerian utility sector. Its financial burden adversely affects the cash flows and overall performance of electricity service providers. Case studies in high-theft contexts indicate that revenue lost to non-

technical losses, of which theft is the principal component, often amounts to 10%-40% of the total turnover of affected utilities (N. Ofoegbu & E. Emengini, 2013). The analysis of electricity-theft dynamics in high-loss environments provides valuable insights for developing countries such as Nigeria, where the scale of the problem is well documented. Far-reaching findings have emerged from more than 40 case studies of non-technical losses conducted in several countries, including Brazil, China, India, Indonesia, Kenya, Mexico, Pakistan, South Africa, and Uganda (Joaquim et al., 2017). These investigations have yielded a variety of technical, regulatory, consumer engagement, and economic proposals to reduce non-technical losses. Within Nigeria, preliminary project activities have already indicated the need for similar approaches. The financial implications of non-technical losses depend on a utility's overall billing and collection efficiency; consequently, addressing these losses should be considered as a separate, parallel intervention that complements ongoing revenue-recovery efforts.

9. Policy Implications for Nigeria

Financing through the World Bank and other international agencies must be pursued for investments in advanced metering infrastructure and other initiatives to reduce theft. Expanded universal access to power supply is required to ensure financial sustainability and ensure that all Nigerians have affordable, reliable access to power. Four recommendations emerge from the preceding analysis of non-technical losses in Nigeria. First, the government should use and document the petroleum subsidy elimination process to remove the electricity subsidy, enabling full-cost recovery and financing theft-recovery initiatives. Second, a fiscally neutral, equitable financing arrangement should be established among utility operators, the government, and other sources to address the effects of electricity theft. Third, the finances of the nation's electricity sector should be prioritised for support by international agencies. Finally, a comprehensive approach across technical, regulatory, customer, and economic dimensions is essential for the financial sustainability of electricity supply in Nigeria (N. Ofoegbu & E. Emengini, 2013).

10. CONCLUSION

Electricity theft is the primary commercial failure in Nigeria's power sector, driving non-technical losses, weakening cash flow, and undermining service quality. This paper sets out a practical pathway to reverse that equilibrium. First, measure losses precisely through robust data governance, analytics, and field insight. Second, target interventions where

incentives bite: metering integrity and AMI, clear anti-fraud protocols, tariff rationalisation with protections for the vulnerable, and customer engagement that rebuilds trust. Third, align financing and regulation with verified results via performance-based mechanisms and bankable cost-recovery for loss-reduction investments. Finally, sequence delivery through a phased, role-clear roadmap and track progress with a compact indicator set: revenue recovery, loss-reduction rate, operating margin, and cash-flow health. Done together, these steps can cut theft at scale, stabilise liquidity, and create the credibility needed to expand reliable, affordable power.

REFERENCES

1. Obafemi, M. O. J. O. (2021). Determinants, prevalence and effects of electricity theft among households in Lagos State.
2. Hu, W., Yang, Y., Wang, J., Huang, X., & Cheng, Z. (2020). Understanding Electricity-Theft Behaviour via Multi-Source Data.
3. N. Ofoegbu, G., & E. Emengini, S. (2013). Recovery of Cost of Electricity Supply in the Nigerian Power Sector.
4. Mbanjwa, T. (2017). An analysis of electricity theft: the case study of KwaXimba in eThekwini, KwaZulu-Natal.
5. Skaloumpakas, P., Sarmas, E., Rachmanidis, M., & Marinakis, V. (2024). Reshaping the energy landscape of Crete through renewable energy valleys. Scientific Reports, 14(1), 8038.
6. Obiora, G. N., Igbinosa, G. O., & Fiemobebefa, C. B. (2025). Technical Losses across Distribution Networks in Nigeria and Mitigative Measures: A Review. ABUAD Journal of Engineering Research and Development (AJERD), 8(1), 43–49. Abro, S. A., Laghari, J. A., Memon, S. A., Khan, T. A., Memon, I., Nasir, H., & Fatima, K. (2025). Non-technical loss detection in power distribution networks using machine learning. Scientific Reports, 15(1), 36189.
7. Olanrele, I. (2025). Analysis of Determinants of Electricity Theft in Nigeria. Journal of Economics and Allied Research (JEAR), 185.
8. Joaquim, V., Paulo, E., Rui, M., Victor, M., & Susana, V. (2017). Solutions for detection of non-technical losses in the electricity grid: a review.
9. Ndulaka, J. S., Nwele, E. O., Olubiwe, M., & Akwukwaegbu, I. O. (2025). Anti-Electricity Theft Model for Sustainable Economic Development in Nigeria. International Journal of Electrical, Energy and Power System Engineering, 8(2), 128-141.

10. Özay, E. C. & Çakıt, E. (2025). Assessing the relationship between electricity theft and customer payment habits: A machine-learning approach. Utilities Policy.
11. Goyal, S. & Mukherjee, M. (2025). Flood-Induced Loss and Damage Estimation Models: A State-of-the-Art Review. IDRiM Journal.
12. Rajaguru, S., Johansson, B., & Viscusi, G. (2024). Users' understanding of smart meters in Sweden: an interpretive study. In 9th Workshop on Managed Complexity (ManComp, 2024), Prague, Czech Rep., September 11-13, 2024 (pp. 119–133).
13. Sibiya, C. A. & Ogudo…, K. A. (2024). Electricity Theft in Sub-Saharan Africa: A Review. … African Universities Power
14. Aniedu, A. N., Inyiama, H. C., Azubogu, A. C., & Nwokoye, S. C. (2021). Pattern recognition using support vector machines to address non-technical losses in the electricity distribution industry. International Journal of Innovative Science and Modern Engineering (IJISME), 7(2).
15. Gershon, O. & Ezurum, A. (2017). Energy Sector Governance and Cost-Reflective Pricing in West Africa.
16. Eniola Victor, O. (2017). Factors contributing to the poor performance of electricity service privatisation in Ekiti State, Nigeria.
17. Salman, A. (2016). Risk-Based Assessment and Strengthening of Electric Power Systems Subjected To Natural Hazards.
18. Eberhard, A., Mountain, B., Pickering, M., & van Horen, C. (2016). Electrification financing and tariffs: international literature review.
19. Adebayo, A. V., Oladeji, S., & Adebayo, H. K. (). Analysing the Impact of Attacks and Vandalism on Nigerian Electricity Transmission Lines: Causes, Consequences, and Mitigation Strategies. researchgate.net.
20. Adebayo, A. V., & Ainah, P. K. (2024). Addressing Nigeria's Electricity Challenges: Past, Present, And Future Strategies. American Journal of Applied Sciences and Engineering, 5(2), 1–16.
21. Joshua Olujobi, O., Emena Okorie, U., Smaranda Olarinde, E., & Deborah Aina-Pelemo, A. (2023). Legal responses to energy security and sustainability in Nigeria's power sector amidst fossil fuel disruptions and low-carbon energy transition.