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Gas Utilization Through Processing and Distribution Reforms in Nigeria's Petroleum Industry Act

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ABSTRACT

Nigeria possesses Africa's largest proven natural gas reserves, and persistently flared associated gas for over six decades, incurring cumulative economic losses estimated at US$56.75 billion in direct revenue and US$120.15 billion in broader opportunity costs between 2002 and 2024. The enactment of the Petroleum Industry Act (PIA) in 2021 introduced a comprehensive regulatory architecture designed to utilize gas from waste disposal into a commercial resource stream. This article critically examines the midstream and downstream processing and distribution reforms in Nigeria's PIA framework, evaluating effectiveness through systematic review of empirical studies, regulatory instruments, and operational data. Drawing on quantitative research demonstrating that post-2018 flare tariff increases achieved a statistically significant 9.26 %-point reduction in flaring volumes at the 1% significance level, this paper argues that regulatory stringency interacts with infrastructure availability to determine outcomes. The analysis reveals that the critical constraint has shifted from upstream prohibition to midstream offtake capacity, processing infrastructure, and distribution network adequacy. We highlight institutional innovations that have been developed, yet governance challenges threaten implementation. This article proposes an integrated framework prioritizing modular processing technologies, virtual pipeline distribution models, aggregation strategies, and stringent fiscal accountability mechanisms to actualize the PIA's mandate of converting wasted flare gas.

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INTRODUCTION

For over six decades, the flare stack has remained the most persistent symbol of Nigeria's petroleum resource paradox—a country defined by energy abundance and widespread energy poverty. Nigeria holds approximately 206 trillion standard cubic feet of natural gas reserves, positioning it as Africa's largest gas-endowed nation and the ninth globally. Yet this wealth has historically been treated as a nuisance by-product of oil extraction. The consequence has been systematic gas flaring inflicting cumulative environmental, economic, and public health damages of extraordinary magnitude.

The scale of this resource waste has attracted sustained scholarly attention. Giwa et al. (2019) documented gas flaring's environmental and health impacts in the Niger Delta, establishing correlations with respiratory and cardiovascular disease prevalence. Ajugwo (2013) earlier established negative health implications for host communities, while Nriagu et al. (2016) characterized heavy metal contamination footprints associated with decades of hydrocarbon operations. Recent quantitative analysis has quantified cumulative economic losses with unprecedented precision. A comprehensive environmental economic assessment covering 2002 to 2024 calculated cumulative flaring emissions of 714.62 million tonnes of carbon

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dioxide equivalent, direct revenue losses of US$56.75 billion, and broader economic opportunity costs reaching US$120.15 billion (Anyanwu et al., 2025). These figures exceed the capital requirements for comprehensive gas infrastructure development by multiples.

Nigeria's trajectory within the global flaring landscape reflects both the challenge's magnitude and reform complexity. The World Bank consistently ranks Nigeria among the top seven to nine flaring nations—countries collectively accounting for approximately 75% of global flaring. By 2023, Nigeria reduced flaring by 1.3 billion cubic meters, representing a 20% reduction from 2021 levels, moving from seventh to ninth position globally (World Bank, 2024). However, this reduction was partially attributable to a 14% decline in oil production during 2021-2022, raising questions about whether reductions represent efficiency gains or output contraction.

The legislative history of Nigeria's engagement with gas flaring reveals a pattern of prohibition without implementation capacity. The Petroleum (Drilling and Production) Regulations of 1969first mandated gas utilization proposals. The Associated Gas Reinjection Act of 1979 declared flaring illegal with an operative date of 1985, subsequently amended in 1992, 1998, and 2018. The Gas Flaring Prohibition and Punishment Act of 2005 set a long-standing regulatory tone, yet enforcement remained inconsistent, undermined by penalties operators treated as nominal business costs (Olujobi et al., 2025). The 2018 Flare Gas Regulations marked an inflection point, increasing the tariff by a factor of 38 relative to the preceding regime.

The Petroleum Industry Act of 2021 represented a legislative milestone-a comprehensive legal framework designed to overhaul Nigeria's petroleum sector governance after more than 50 years under the Petroleum Act of 1969. The PIA's gas provisions fundamentally reconceptualize the legal status of flare gas: no longer a waste product subject to nominal penalties, but a national resource with vested commercial rights assigned to the state through the Nigerian Upstream Petroleum Regulatory Commission. This transformation from a punitive model to a commercialization paradigm constitutes the PIA's most significant innovation in gas governance.

Yet legislative intent alone cannot compress gas, build pipelines, or construct processing facilities. The PIA provides the legal mandate, commercial rights assignment, and penalty architecture. What remains critically underdeveloped is the physical infrastructure and institutional capacity required to capture, process, transport, and distribute natural gas to end-users across Nigeria's geographically dispersed demand landscape. This article argues that Nigeria's gas-to-fuel transition is fundamentally a midstream and downstream engineering and governance challenge, requiring integration of regulatory design with infrastructure deployment, fiscal accountability, and demand-side market development.

The analysis proceeds through six substantive sections. Section 2 evaluates the regulatory architecture under the PIA and subsidiary 2023 Regulations. Section 3 analyses quantitative evidence on market-based instruments' effectiveness. Section 4 examines midstream processing constraints and infrastructure gaps. Section 5 evaluates distribution infrastructure and governance challenges. Section 6 synthesizes comparative perspectives. Section 7 proposes an integrated strategic framework for actualizing the PIA's gas commercialization mandate.

The PIA Legal Architecture: Reconfiguring Flare Gas Property Rights

The Petroleum Industry Act of 2021 represents Nigeria's most ambitious legislative intervention in gas governance. Understanding its innovation requires contrasting it with the legal regime it replaced—a layered accumulation of statutes that prohibited flaring in principle while systematically enabling it in practice.

The Pre-PIA Regulatory Inheritance

Nigeria's statutory engagement with gas flaring predates the PIA by over five decades. The Petroleum (Drilling and Production) Regulations of 1969 mandated gas utilization proposals for new

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fields, representing the earliest regulatory acknowledgement that flaring constituted resource waste. The Associated Gas Reinjection Act of 1979 declared flaring illegal effective January 1984and introduced Nigeria's first penalty regime. Subsequent amendments revised the penalty three times—in 1992,1998, and 2018-each increasing nominal charges without fundamentally altering operator incentives.

The critical weakness of this pre-PIA architecture lay in the penalty structure. Before 2018, flare penalties were set at levels operators rationally treated as operational costs rather than behavioural deterrents. The 2018 Flare Gas Regulations marked a regulatory inflection point, increasing the tariff by a factor of 38—from negligible levels to an average of USD 2.50 per thousand standard cubic feet-providing the first empirical test of whether price-based instruments could influence flaring behaviour in Nigeria.

The regulatory fragmentation of the pre-PIA era further undermined effectiveness. Multiple statutes with overlapping jurisdictions, inconsistent definitions, and uncoordinated enforcement created an institutional landscape where responsibility for flare reduction was simultaneously everyone's mandate and no one's accountability. Olujobi et al. (2025) concluded that Nigeria's pre-PIA framework suffered from "fragmented oversight" in contrast to Norway's "centralized, infrastructure-driven regulatory framework."

The PIA Property Rights Transformation

The PIA's foundational innovation lies in its reconceptualization of property rights over flared gas. Section 33 vests ownership of all gas at the flare point in the Federal Government, designating the Nigerian Upstream Petroleum Regulatory Commission as the administrative authority with exclusive power to issue Permits to Access Flare Gas. This provision fundamentally alters flare gas's legal character from a valueless by-product subject only to modest penalties into a state-owned resource with defined commercial rights.

The 2023 subsidiary regulations operationalize this framework through several interconnected mechanisms. The Gas Flaring, Venting and Methane Emissions Regulations mandate that all petroleum producers submit a Flare Elimination and Monetization Plan to the NUPRC, specifying methodology, technology pathway, and implementation timeline. This transforms flare management from an aspirational policy objective into a legally binding operational obligation tied to license maintenance. Upon regulatory approval, producers enter into a Milestone Development Agreement—a contractual instrument creating enforceable performance commitments with specified indicators, timeframes, and consequences for non-compliance.

The regulatory architecture further introduces a bifurcated permitting system distinguishing between routine and emergency flaring. Routine flaring below NUPRC-approved thresholds attracts a flaring fee calibrated to function as an economic disincentive. Emergency flaring—releases necessitated by safety conditions, equipment failures, or operational disruptions—is exempted. This distinction introduces regulatory nuance absent from earlier blanket prohibitions.

Crucially, the PIA framework embeds enhanced monitoring and transparency obligations. Producers and permit holders must maintain daily records of all flaring, venting, and fugitive methane emissions. The NUPRC is required to publish annual reports with producer-level flaring data. This data infrastructure addresses a persistent weakness identified by Olujobi et al. (2025), who found that Nigeria's flaring data historically lacked granularity and reliability necessary for effective regulatory enforcement.

The Nigerian Gas Flare Commercialization Programme

The NGFCP constitutes the practical implementation mechanism for the PIA's commercialization mandate. Operating through competitive bid rounds, the programme awards flare gas permits to qualified applicants

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demonstrating technical and financial capacity to capture and commercialize gas from designated flare sites. To date, the NUPRC has issued 49 awards targeting the elimination of an estimated 500 million standard cubic feet of gas from flaring.

A structural innovation is the establishment of a College of Awardees—an interactive platform bringing together financiers, permit recipients, technology providers, and regulatory officials. This collaborative architecture reflects institutional learning about coordination failures that have historically undermined Nigerian gas projects. The NGFCP has pursued international technology partnerships, including with Galileo Technologies, an Argentine engineering firm specializing in modular gas processing solutions. Galileo's technology portfolio—scalable, skid-mounted liquefaction and compression systems-offers rapid deployment to remote well sites without requiring extensive fixed pipeline connections.

The Decade of Gas and Strategic Integration

The PIA's gas provisions connect to a broader national energy strategy articulated through the "Decade of Gas" initiative, targeting over 12 billion cubic feet per day of gas supply by 2030. This vision encompasses multiple end-use pathways: the LPG Penetration Programme targeting five million households for clean cooking transition; industrial gas supply expansion; and completion of strategic trunk pipeline projects including the OB3 and AKK systems.

The 2025-2030 Strategic Plan under development integrates these elements, defining measurable performance indicators for gas monetization, domestic refining capacity, and energy transition alignment. A dedicated committee inaugurated in October 2025 oversees oil and gas sector reforms, with explicit terms of reference encompassing coordination challenges that have historically fragmented Nigerian energy policy implementation.

The institutional architecture established by the PIA creates multiple implementation agencies with overlapping responsibilities: NUPRC (upstream regulation and flare commercialization), NMDPRA (midstream and downstream regulation and MDGIF administration), NNPC Limited (commercial operator and infrastructure developer), and the Ministry of Petroleum Resources (policy direction). This multi-agency structure has been identified as requiring "stronger inter-agency coordination."

The Quantitative Evidence: Do Regulatory Tariffs Curb Gas Flaring?

The PIA's regulatory framework operates on an implicit theory of change: those sufficiently stringent economic disincentives, combined with legal prohibitions and commercialization pathways, will alter operator behaviour. Until recently, this proposition lacked rigorous empirical testing in the Nigerian reality.

The Tariff Effectiveness Study: Methods and Findings

A 2025 study by the Centre for Energy and Petroleum, Mineral Law and Policy at the University of Dundee provides the first quantitative assessment of flare tariff effectiveness in Nigeria. Using a 52-year dataset, the researchers employed multivariate linear regression models to isolate the effect of flare tariff levels on flaring volumes while controlling for oil production, oil prices, gas prices, and gas infrastructure availability (Centre for Energy and Petroleum, Mineral Law and Policy, 2025).

The analytical design exploited a natural experiment created by Nigeria's regulatory history. The 2018 Regulations increased the flare tariff by a factor of 38, creating two distinct policy periods with dramatically different penalty levels. TThe results are striking: pre-2018 tariffs were associated with a statistically insignificant reduction of 0.05 percentage points, confirming the earlier regime's ineffectiveness. The post-2018 regime produced a 9.26 percentage-point decline in flaring volumes, statistically significant at the 1% level (Centre for Energy and Petroleum, Mineral Law and Policy, 2025).

However, the study also reveals the limits of price-based instruments. Beyond tariff levels, oil production volumes, oil prices, and—crucially—gas infrastructure availability emerged as significant determinants of flaring outcomes.

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This multi-causal finding validates the central argument of this article: regulatory stringency is a necessary but insufficient condition for flaring reduction. Without parallel expansion of processing and distribution infrastructure, even substantial tariffs cannot achieve intended behavioural effects because operators lack viable alternatives to flaring.

Corroborating Evidence on Infrastructure Constraints

The Dundee study's findings align with broader empirical research on Nigeria's gas sector. Anyanwu et al. (2025) documented that cumulative flaring-related economic losses of US$120.15billion far exceed the capital required for comprehensive gas infrastructure development, suggesting that the economic case for aggressive investment is overwhelming. Giwa et al. (2019) established through pollutant dispersion modelling that flare emissions create localized concentration zones exceeding World Health Organization guidelines, with health costs that compound the direct economic losses.

Nnadikwe et al. (2024) employed process simulation tools including Aspen HYSYS, Finite Element Analysis, and Computational Fluid Dynamics to evaluate domestic natural gas transportation sustainability in Nigeria. Their findings indicate that achieving 45% local utilization of natural gas can significantly enhance GDP growth, with technical specifications for a 24-inch carbon steel pipeline and process separation simulation providing engineering parameters for infrastructure planning.

Akinyemi and Adebayo (2023) examined the macroeconomic determinants of gas flaring in Nigeria using autoregressive distributed lag modelling, finding that domestic gas utilization and infrastructure investment were significant negative predictors of flaring volumes, while oil production was a positive predictor. These findings reinforce the conclusion that infrastructure availability operates independently of regulatory stringency in determining flaring outcomes.

Interpreting the Evidence: Tariffs as Necessary but Insufficient

The 9.26 percentage-point reduction attributable to post-2018 tariffs represents genuine progress, demonstrating that Nigerian operators respond to sufficiently stringent economic incentives when those incentives alter the cost-benefit calculus of continued flaring versus investment in capture infrastructure (Centre for Energy and Petroleum, Mineral Law and Policy, 2025). At USD 2.50per thousand standard cubic feet under the 2018 Regulations—and now USD 3.50 under the PIA—the flare tariff has crossed a threshold where payment exceeds the per-unit cost of many modular gas capture technologies (Centre for Energy and Petroleum, Mineral Law and Policy, 2025).

Yet the persistence of substantia1 flaring volumes despite tariff escalation underscores the infrastructure constraint. Operators cannot capture and commercialize gas if processing facilities lack available capacity, if pipeline connections do not exist between well sites and demand centres if potential off takers face credit risks that render supply contracts non-bankable. In such conditions, even the most stringent tariff functions as a revenue instrument for the government rather than a behavioural change mechanism-operators pay the fee as a cost of continued production because physical alternatives remain unavailable.

The study's finding that gas infrastructure availability independently predicts flaring outcomes confirms this interpretation (Centre for Energy and Petroleum, Mineral Law and Policy, 2025). It suggests that the marginal impact of additional tariff increases will diminish unless accompanied by parallel expansion of processing, transportation, and distribution capacity. This finding has direct policy implications: the optimal strategy is not simply continued tariff escalation but simultaneous investment in the physical infrastructure that enables operators to respond to tariff incentives.

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Midstream Processing Constraints: The Infrastructure Bottleneck

The quantitative evidence that infrastructure availability independently determines flaring outcomes directs analytical attention to specific physical constraints limiting Nigeria's capacity to absorb captured gas into productive channels.

Pipeline Network Fragmentation

Nigeria's domestic gas transmission infrastructure remains geographically concentrated and capacity-constrained relative to production volumes. The Escravos-Lagos Pipeline System, the country's principal gas transmission artery, operates near its design capacity, limiting incremental gas injection from new capture projects (Nigerian Gas Company, 2023). The Nigerian Gas Company progressively expanded transmission capacity to approximately 2.9 billion standard cubic feet per day as of 2019, yet this capacity remains substantially below the volume required to absorb current flaring levels while simultaneously serving existing power generation and industrial demand (Nnadikwe et al., 2024).

The pipeline network's coastal concentration reflects the historical development pattern of Nigeria's petroleum industry, which oriented infrastructure toward export terminals rather than domestic distribution. Oyewunmi and Olawuyi (2020) examined Nigeria's gas-to-power value chain, identifying infrastructure deficits as the binding constraint on domestic gas utilization and recommending integrated planning approaches that align pipeline development with power generation expansion.

Two strategic pipeline projects aim to address this transmission constraint, though both have experienced extended implementation timelines. The OB3 pipeline, connecting eastern production hubs to the western network, endured over a decade of delays attributable to contractual disputes, community obstructions, and funding gaps (Ekong, 2023). The Ajaokuta-Kaduna-Kano (AKK)pipeline has been designed to transport gas from the southern network through Abuja to Kano in the north-represents the most ambitious domestic gas infrastructure project in Nigerian history. Inuwa and Onuoha (2023) analysed the AKK project's economic viability, concluding that while the projected industrial corridor benefits are substantial, project finance and community engagement risks require proactive mitigation.

The capital intensity and extended construction timelines of these trunk pipeline projects illustrate a fundamental tension: the facilities capable of absorbing volumes being prohibited from flaring require years and billions of dollars to construct, while flaring continues at rates inflicting daily economic and environmental costs. This temporal mismatch between regulatory ambition and infrastructure delivery explains the observed pattern where tariff increases achieve partial reductions, but the binding constraint progressively shifts from regulatory disincentive to physical capacity.

Modular Processing Solutions for Flare Capture

For flare capture specifically, the NGFCP's emphasis on modular processing technologies reflects a pragmatic assessment of Nigeria's infrastructure challenge. Conventional gas monetization assumes large, centralized facilities requiring multi-billion-dollar capital commitments and decade-long development timelines. These facilities are economically viable only when aggregating gas from multiple large fields.

Modular technologies challenge this paradigm by enabling incremental capacity additions at lower unit scale, reducing minimum economic field size thresholds, and permitting deployment at remote locations. Containerized and skid-mounted systems can be prefabricated, minimizing on-site construction requirements. They can be redeployed as field conditions change and replicated across multiple flare locations.

Okafor and Nwosu (2024) evaluated the techno-economic feasibility of containerized mini-LNG systems, finding that units processing 5-15 million standard cubic feet per day can achieve positive net present values at gas prices competitive with diesel and LPG alternatives.

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Their sensitivity analysis identified gas price, capacity utilization rate, and financing cost as the variables most significantly affecting project viability.

Power Sector Demand and Legacy Debt Resolution

The power generation sector represents the largest potential domestic demand sink for captured flare gas. Gas-fired plants account for approximately 70% of Nigeria's grid-connected electricity generation, yet chronic underutilization persists due to transmission constraints, distribution company insolvency, and upstream gas supply interruptions triggered by payment arrears (Adenikinju, 2020).

The payment risk problem has created a self-reinforcing cycle undermining the gas-to-power value chain. Distribution companies face revenue collection challenges and tariff constraints limiting their ability to pay generation companies. Generation companies, facing uncertain payments, accumulate arrears to gas suppliers. Gas producers, facing payment default risk, reduce supply or redirect gas to more reliable off takers-including export LNG facilities. The resulting supply interruptions reduce power generation, further undermining distribution company revenues (Adenikinju, 2020).

The Federal Government's December 2025 decision to authorize settlement of N185 billion in legacy debts owed to gas producers represents a significant intervention (Shuaibu, 2025). The Coordinating Director of the Decade of Gas Secretariat characterized the debt clearance as "powerful signal of commitment" that could "unlock stalled projects, revive investor interest and rebuild momentum" (Shuaibu, 2025). The settlement mechanism employs a royalty offset arrangement allowing producers to recover amounts against future obligations rather than requiring immediate treasury cash outlays.

From an engineering economics perspective, the debt settlement addresses a critical failure mode in the gas-to-power value chain. Even with available processing and transport infrastructure, gas will not flow to applications were payment risk renders supply contracts unbankable. Iledare and Suberu (2022) examined the fiscal regime and gas development in Nigeria, arguing that payment security for domestic gas supply requires institutional mechanisms—such as the royalty offset arrangement—that reduce counterparty risk to levels acceptable for project finance.

DISTRIBUTION INFRASTRUCTURE AND GOVERNANCE CHALLENGES

The Midstream and Downstream Gas Infrastructure Fund

Section 52 of the PIA established the MDGIF as the dedicated financing mechanism for gas distribution infrastructure. The Fund's statutory design incorporates a dedicated revenue stream: a 0.5% levy on the wholesale price of petroleum products and natural gas sold in Nigeria, collected from wholesale customers (Federal Republic of Nigeria, 2021). This earmarked funding mechanism was designed to provide predictable, non-budgetary financing for infrastructure development, insulating critical gas investments from the uncertainties of annual appropriation cycles.

The MDGIF's design reflects international best practice in infrastructure finance. Dedicated funding streams with clear collection obligations, defined utilisation purposes, and institutional separation from general government revenues address the time inconsistency problem that undermines infrastructure investment in budget-dependent systems. Ekeocha and Ogbuabor (2023) analysed infrastructure financing mechanisms in Nigeria's petroleum sector, concluding that dedicated funds with statutory revenue sources outperform budget-dependent appropriations in achieving infrastructure delivery targets-but only when governance mechanisms ensure fiscal accountability.

However, the Fund's implementation has attracted significant governance scrutiny that threatens its legitimacy and effectiveness. In August 2025, the House of Representatives Public Accounts Committee raised formal concerns about alleged misapplication and

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mismanagement of MDGIF resources by NMDPRA, the agency charged with administering the Fund (House of Representatives, 2025). The Committee documented that NMDPRA had failed to respond to formal requests for information on Fund administration and utilization, and subsequently failed to honour an invitation to appear before the Committee.

In response, the House ordered a comprehensive forensic audit of all MDGIF operations from 2021 to date, to be conducted by the Office of the Auditor-General for the Federation within 60days (House of Representatives, 2025). The audit's terms of reference encompass identification of wholesale customers who failed to remit the required levy, investigation of expenditure decisions, and assessment of whether allocated funds reached intended infrastructure projects in completed, operational form.

This governance challenge is not peripheral to the technical question of gas distribution but central to it. A dedicated infrastructure fund-however elegantly designed in statute—that does not translate into constructed pipelines, processing plants, and distribution networks represents a critical failure mode in the PIA's implementation architecture. The MDGIF controversy illustrates a recurring pattern documented by Sayne and Gillies (2021) in their analysis of national oil company governance: well-designed institutional mechanisms undermined by opaque administration, inadequate transparency, and insufficient accountability for resource stewardship.

LPG Distribution and the Clean Cooking Transition

The household cooking gas market illustrates the distribution challenge at its most granular level—reaching millions of dispersed, often low-income consumers with a product requiring specialized handling, storage, and safety infrastructure. Despite Nigeria's vast gas resource endowment, LPG penetration remains low. A substantial portion of households, particularly in rural areas, rely on biomass fuels (firewood, charcoal) and kerosene for cooking. The resulting indoor air pollution burden contributes to respiratory disease prevalence, while deforestation pressures from fuelwood collection compound environmental degradation (World Health Organization, 2021).

The government's LPG Penetration Programme targets the transition of five million households to clean cooking gas by 2030 through a dual strategy of demand stimulation—free cylinder distribution to overcome upfront cost barriers—and supply expansion through increased domestic production and import terminal capacity (EnviroNews Nigeria, 2025). The Minister of State for Petroleum Resources (Gas) has reported that cylinder distribution has been implemented across five of Nigeria's six geopolitical zones, with the South-East yet to be covered (EnviroNews Nigeria, 2025).

From a distribution infrastructure perspective, the LPG programme highlights the logistical complexity of reaching dispersed consumers. LPG requires a multi-echelon supply chain: primary storage terminals at coastal import or production points; secondary filling plants serving regional markets; branded cylinder distribution networks reaching retail outlets; and last-mile delivery to households. Nwankwo and Obi (2023) examined the economics of LPG distribution in Nigeria, finding that infrastructure costs per consumer served increase exponentially with distance from primary storage and with decreasing population density, making rural distribution economically challenging without cross-subsidization or targeted government support.

Obioma and Ekwueme (2022) analysed the clean cooking transition challenge in Nigeria through the lens of energy justice, arguing that policy interventions must address the affordability dimension alongside infrastructure availability. Their analysis found that the upfront cost of LPG cylinders and stoves represents a barrier that the government's cylinder distribution programme partially addresses, but that ongoing fuel costs relative to household income remain a constraint for sustained adoption among lower-income households.

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CNG and Virtual Pipeline Networks

Compressed Natural Gas offers an alternative distribution model with specific advantages for Nigeria's infrastructure profile. Unlike LPG, which requires either cryogenic liquefaction or pressurized storage as a liquid, CNG can be produced through simpler compression at the gas source and transported via high-pressure tube trailers to off-takers. This "virtual pipeline" approach decouples gas distribution from fixed pipeline infrastructure (Nnadikwe et al., 2024).

The PIA framework explicitly promotes CNG and mini-LNG as distribution modalities suited to Nigeria's current infrastructure realities (Federal Republic of Nigeria, 2021). By enabling gas transportation without requiring completed trunk pipeline projects, virtual pipelines offer a bridging strategy: gas can reach markets during the extended period required for fixed infrastructure construction, generating revenues that improve the investment case for permanent pipeline connections.

Nnadikwe et al. (2024) conducted technical-economic analysis of CNG virtual pipeline systems for Nigerian industrial clusters, finding that tube trailer delivery can be cost-competitive with diesel and low-pour fuel oil for distances up to 200 kilometres from compression stations, depending on road conditions, diesel price assumptions, and utilisation rates. Their analysis identified clustering of industrial demand as the key variable determining viability, with dispersed, low-volume consumers unlikely to sustain virtual pipeline economics without aggregation.

The constraint on virtual pipeline expansion is demand aggregation. CNG economics depend on sufficient offtake volumes within a radius where transport costs do not erode margins below viability thresholds (Okafor & Nwosu, 2024). Industrial parks, power generation facilities, and concentrated commercial zones offer viable demand anchors; dispersed rural households typically do not. This demand geography requirement shapes which captured gas volumes can be monetized through virtual pipelines and which require alternative distribution pathways, including LPG conversion for household markets.

Community Dimensions and the Social License to Operate

The distribution infrastructure challenge extends beyond engineering and economics to encompass community engagement and the social license to operate. The Niger Delta's experience of environmental degradation from decades of hydrocarbon operations has created profound community distrust of oil and gas infrastructure projects (Nriagu et al., 2016; Ajugwo, 2013).

Okonkwo and Eze (2022) examined community perspectives on gas flare commercialization projects in Delta State, finding that while communities express support for flare elimination, they also prioritise local employment, community equity participation, and environmental remediation as conditions for accepting new gas infrastructure. Their findings suggest that project developers must engage communities not merely as project-affected persons requiring compensation but as stakeholders with legitimate interests in project design, benefit-sharing, and environmental management.

Ebeniro and Okafor (2022) similarly found that the gas flare elimination policy's success depends on community engagement as a critical success factor alongside technical and financial viability. The PIA's Host Communities Development Trust provisions (Chapter 3) create a statutory framework for community benefit-sharing from petroleum operations, requiring operators to contribute 3% of their annual operating expenditure to community development trusts (Federal Republic of Nigeria, 2021). The effectiveness of these provisions in building community support for gas infrastructure projects remains to be evaluated.

COMPARATIVE PERSPECTIVES AND REFORM PATHWAYS

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Norway's Centralized Infrastructure Model

Norway consistently appears in comparative studies as the benchmark jurisdiction—a petroleum-producing nation that has virtually eliminated routine flaring through stringent regulation, comprehensive infrastructure investment, and institutional integration. Norway's regulatory framework integrates strict flaring limits with high penalties for non-compliance and, crucially, substantial state investment in gas capture and processing infrastructure (Bribena & Ohimor, 2025;Olujobi et al., 2025).

The Norwegian model's distinguishing feature is the alignment of regulatory prohibition with infrastructure availability. When Norway imposed strict flaring limits, operators had access to constructed gathering systems, processing facilities, and pipeline connections to European gas markets (Thurber et al., 2020). The regulatory mandate and physical capacity to comply were sequenced appropriately, contrasting with Nigeria's approach where prohibition has repeatedly outrun infrastructure provision.

Norway's centralized, infrastructure-driven regulatory framework, administered through coherent institutional arrangements rather than fragmented agency responsibilities, represents the institutional dimension of this success (Thurber et al., 2020). Olujobi et al. (2025) argue that Nigeria should restructure its multi-agency gas governance model toward greater institutional coherence, recognizing that coordination failures across NUPRC, NMDPRA, NNPC Limited, and the Ministry of Petroleum Resources undermine implementation effectiveness.

The United States' Market-Based Approach

The United States employs a multi-tiered regulatory architecture combining federal and state-level regulations with market-based incentives (Olujobi et al., 2025). The U.S. approach leverages the depth of American capital markets and the scale of domestic gas demand to create commercial incentives for capture and utilization, with regulation functioning as a backstop rather than the primary driver.

The U.S. model's applicability to Nigeria is constrained by structural differences in capital market development, domestic gas demand depth, and institutional capacity for multi-jurisdictional regulatory coordination (Bribena & Ohimor, 2025). However, the emphasis on transparency and mandatory reporting has direct relevance to Nigeria's PIA implementation, particularly the annual publication requirements that create accountability mechanisms (International Energy Agency,2023).

Algeria's Mandatory Compliance Regime

Algeria offers a comparative case from within Africa's hydrocarbon-producing context. Bribena and Ohimor (2025) found that Algeria's success in gas utilisation resulted from"a mix of stringent regulation, efficient enforcement, and a well-planned infrastructural basis," with environmental impact assessment processes operating as mandatory compliance requirements rather than procedural formalities. This contrasts with Nigeria where EIA processes have been characterised as "weak and ineffective" (Bribena & Ohimor, 2025).

Algeria's experience demonstrates that African institutional contexts can support effective gas governance when political commitment translates into enforcement capacity and infrastructure investment. The contrast with Nigeria suggests that the critical variable is not the sophistication of legal drafting-the PIA is more comprehensive than Algeria's petroleum legislation-but fidelity of implementation.

Saudi Arabia's Master Gas System

Saudi Arabia's Master Gas System represents the preeminent example of large-scale gas infrastructure development transforming flaring outcomes in a major petroleum-producing nation. Initiated in the 1970s, the system integrated gas gathering, processing, and distribution across the country's major oil fields, enabling the Kingdom to reduce flaring to negligible levels while building a petrochemical industry on captured gas feedstock (Thurber et al., 2020).

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The Saudi experience underscores that comprehensive gas infrastructure requires sustained investment over decades and substantial upfront capital commitment. Nigeria's policy of promoting modular, scalable solutions (NUPRC, 2024) represents a pragmatic adaptation to the reality that Nigeria cannot replicate the Saudi approach within the timeframe of its flaring reduction commitments. Modular technologies offer a bridging strategy, achieving incremental reductions while larger infrastructure projects develop.

Lessons for Nigeria's Reform Pathway

Comparative analysis yields several lessons for Nigeria. First, regulatory prohibition succeeds only when sequenced with infrastructure availability—a lesson from Norway and Saudi Arabia that Nigeria's history of premature prohibition confirms. Second, institutional coherence matters: fragmented oversight across multiple agencies undermines implementation, while Norway's centralized accountability creates clear responsibility for outcomes (Bribena & Ohimor, 2025).Third, domestic market development is essential for absorber captured gas volumes, requiring parallel investment in power generation, industrial clusters, and household energy access (Thurber et al., 2020). Fourth, transparency and independent data verification enable accountability and build investor confidence (Olujobi et al., 2025).

Strategic Framework for PIA Implementation

The preceding analysis—integrating quantitative evidence on tariff effectiveness, engineering assessment of infrastructure constraints, and comparative legal analysis of governance requirements—provides the foundation for a strategic framework to actualize the PIA's gas commercialization mandate.

Table 1: Processing and distribution reform priorities under the PIA

Reform area	Technical/policy requirement	Expected contribution
Flare-gas data	Metered flow, pressure, composition, contaminants, location, and demand mapping	Project-specific technology selection and investor confidence
Processing	Compression, separation, dehydration, sweetening, NGL recovery, LPG fractionation	Conversion of raw flare gas into marketable fuel and feedstock
Distribution	Pipelines, virtual pipelines, CNG, LPG logistics, mini-LNG, metering	Connection of processed gas to households, transport, power, and industry
Regulation	DGDO enforcement, flare penalties, licenses, tariffs, open access	Commercial discipline and domestic supply assurance
Environmental control	Methane monitoring, LDAR, routine-flaring prohibition, MRV	Climate credibility and reduced pollution
Social License	Host-community benefits, safety communication, local energy access	Reduced conflict and stronger infrastructure protection

Accelerate Modular Processing Deployment

The NGFCP should prioritize awardees demonstrating near-term deployment capability using proven modular technologies. The Galileo partnership provides one technology pathway, but competition among multiple technology providers should be encouraged to drive cost reduction and contextual innovation (NUPRC, 2024). Award criteria should weight time-to-first-gas heavily, recognizing that immediate flaring reduction value

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exceeds optimization for long-term theoretical cost efficiency. Okafor and Nwosu (2024) provide techno-economic parameters confirming viability of containerized mini-LNG at representative Nigerian flare site scales.

Enforce MDGIF Fiscal Accountability with Transparency Mechanisms

The forensic audit ordered by the House of Representatives must produce public, actionable findings with specified consequences for identified mismanagement (House of Representatives,2025). Beyond the audit, structural reforms to MDGIF administration should include mandatory quarterly public reporting of all collections and disbursements with project-level granularity, independent technical verification that funded infrastructure reaches operational completion, and legislative oversight mechanisms with defined escalation authority for non-compliance. Ekeocha and Ogbuabor (2023) provide a framework for infrastructure fund governance that can inform reform design.

Develop Demand Anchors through Coordinated Offtake Development

Gas capture without established offtake is not commercialization but cost displacement. Policy interventions should target demand aggregation through three mutually reinforcing mechanisms: industrial park development with guaranteed gas supply at viability-enabling prices; power purchase agreement frameworks that render gas-to-power projects bankable by addressing payment risk (Adenikinju, 2020; Iledare & Suberu, 2022); and LPG demand stimulation through cylinder distribution and awareness campaigns creating market pull for processed gas volumes (EnviroNews Nigeria, 2025).

Strengthen Inter-Agency Coordination Architecture

The 2025-2030 Strategic Plan should operationalize coordination through specific institutional mechanisms. A dedicated Gas Infrastructure Delivery Task Force reporting to the Minister of State for Petroleum Resources (Gas), with membership spanning NUPRC, NMDPRA, NNPC Limited, and private sector stakeholders, would provide focused implementation coordination (Shuaibu,2025). The College of Awardees model (NUPRC, 2024) demonstrates that dedicated coordination platforms tailored to specific implementation challenges can function within Nigeria's multi-agency governance structure.

Calibrate Flaring Fees to Complement Infrastructure Investment

The NUPRC should review the flaring fee schedule to ensure fees exceed the levelized cost of modular capture and processing alternatives at representative field scales. The quantitative evidence that post-2018 tariffs achieved statistically significant flaring reductions (Centre for Energy and Petroleum, MMineral Law and Policy, 2025) validates the price-based approach, but the finding that infrastructure availability independently predicts outcomes suggests diminishing returns to further tariff escalation without parallel infrastructure expansion. Fee escalation provisions announced over a defined forward timeline would provide regulatory certainty for investment decisions.

Integrate Independent Monitoring and Verification

The PIA's enhanced monitoring requirements should be reinforced through independent verification mechanisms. The recommendation for "independent monitoring of emissions"(Olujobi et al., 2025) speaks to a persistent credibility gap in Nigerian flaring data. Satellite-based monitoring technologies now enable third-party verification of flaring volumes independent of operator reports (World Bank, 2024). Integrating these technologies into Nigeria's compliance architecture would simultaneously improve data quality for policy evaluation and strengthen the credibility of reported progress toward elimination targets.

Community Engagement and Benefit-Sharing

Distribution infrastructure siting and operation require community acceptance that

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cannot be assumed. Okonkwo and Eze (2022) document community priorities—local employment, equity participation, environmental remediation-that project developers and regulators must address. The PIA's Host Communities Development Trust provisions create a statutory framework, but their effectiveness in building the social license necessary for gas infrastructure expansion requires active implementation rather than pro forma compliance.

CONCLUSION

Nigeria's Petroleum Industry Act establishes one of the most comprehensive legal frameworks for gas flare governance in any petroleum-producing jurisdiction. By vesting flare gas ownership in the state, creating a competitive commercialization process, escalating financial consequences through calibrated tariff structures, and codifying operator obligations in detailed subsidiary regulations, the PIA addresses the upstream regulatory dimension with unprecedented legal clarity. The quantitative evidence that post-2018 tariff increases achieved a statistically significant 9.26percentage-point reduction in flaring volumes validates the Act's underlying theory of change.

However, the finding that gas infrastructure availability independently determines flaring outcomes reveals the limits of price-based instruments without parallel infrastructure expansion. The transition from flaring to fuel is fundamentally a midstream engineering challenge constructing processing plants, pipeline networks, and distribution systems that enable captured gas to reach end-users in productive applications. The PIA's midstream provisions recognize this reality, but the gap between statutory provision and physical implementation remains the critical constraint.

The governance dimension cannot be separated from the technical and economic dimensions. The MDGIF controversy illustrates how opaque administration can undermine well-designed institutional mechanisms. The multi-agency governance structure introduces coordination requirements that Nigeria's public administration has historically struggled to satisfy. The comparative experience of Norway demonstrates that institutional coherence—single-point accountability integrating regulation and infrastructure development—outperforms fragmented responsibilities.

Nigeria's stated target of eliminating routine flaring remains technically achievable. The gas resources are proven. The legal framework is established. Modular processing and virtual pipeline technologies are commercially available. The economic case for investment is overwhelming when cumulative US$120.15 billion in flaring-related opportunity costs is weighed against capital requirements for comprehensive infrastructure development.

What remains to be demonstrated is institutional capacity for implementation-the translation of statutory provisions into constructed and operating gas capture systems, processing plants, and distribution networks. This requires simultaneous progress on multiple fronts: technology deployment at flare sites; completion of trunk pipeline projects; development of industrial, power generation, and household demand; fiscal accountability ensuring infrastructure funds become physical assets; and regulatory consistency maintaining credible compliance expectations over time.

The PIA provides the foundation. The engineering, investment, and governance implementation that builds upon this foundation is the task of the decade ahead, upon which Nigeria's energy transition ambitions and the environmental health of its oil-producing communities substantially depend.

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