

# Natural Gas Supply and Electricity Generation Efficiency: Plant-Level Evidence from Nigeria's Largest Thermal Power Facility

Obasi Gilbert Chukwuemeka and

Department of Energy Economics and Policy, Emerald Energy Institute University of Port Harcourt

Yirakpoa Patience Nwambo

Department of Chemical Engineering, University of Port Harcourt

**Abstract** - This study analyzes the influence of natural gas supply dynamics on electricity generation efficiency utilizing operating data from Egbin Power Plant, Nigeria's largest gas-fired thermal power facility. Descriptive statistics, correlation analysis, and multiple linear regression were employed to assess the link between gas-supply variables (including nomination, allocation, and actual off take quantities) and power output over a thirty-month period. The findings indicate that electricity generation is highly and statistically significantly influenced by actual fuel consumption; actual gas offtake is almost universally positively linked with power output ( $r$  0.968) and serves as the primary predictor in the regression model. The gas coefficient is predicted to be between 3.9 and 4.3, indicating that an increase in natural gas supply (1 MMSCFD) results in an approximate increase of 4 MW in electricity output. Conversely, the volumes of nomination and allocation are rendered statistically insignificant in the context of actual offtake. The findings suggest that generating variability is affected by fuel delivery constraints rather than limitations in installed capacity. This article presents actual data at the plant level about fuel productivity in a fuel-constrained electricity market and illustrates the economic importance of reliability in gas supply.

**Keywords:** Natural gas supply, electricity generation, fuel constraints, gas-to-power, power plant

## 1. INTRODUCTION

Natural gas is important in present-day electrical systems owing to its comparatively reduced carbon intensity, operational flexibility, and cost-effectiveness relative to other fossil fuels (Mohammad et al., 2021; Adeola et al., 2021). In resource-abundant emerging nations, natural gas is frequently regarded as a pivotal transition fuel that may facilitate industrialization, provide grid stability, and promote economic progress (Gürsan and de Gooyert, 2020). The efficient operation of gas-fired power is largely dependent upon the dependability of upstream supply chains. Instability in fuel supply can markedly disrupt generation efficiency, capacity utilization, and investment results (Agbonifo, 2016; Mohammad et al., 2021). Nigeria exemplifies a notable contradiction in this context. Notwithstanding its status as home to one of the globe's most extensive confirmed natural gas reserves, energy generation continues to be severely limited (Occhiali and Falchetta, 2018). Gas-fired power plants represent the majority portion of existing capacity; nevertheless, actual generation often lags behind potential levels (Mohammad et al., 2021). Although infrastructural constraints, security issues, and regulatory inefficiencies are frequently mentioned, actual data measuring the impact of gas supply dynamics on plant-level generation performance is few (Oyewunmi and Iwayemi, 2016). The current literature on Nigeria's energy industry predominantly highlights macro-level analysis, concentrating on regulatory frameworks, market reforms, and systemic inefficiencies (Nelson, 2015; Oyewunmi and Iwayemi, 2016). While these investigations yield significant insights into structural restrictions, they provide a limited comprehension of operational reality at the plant level. The economic ramifications of variations between projected gas quantities and actual fuel supplies have not been well quantified (Mohammad et al., 2021). In the absence of detailed data, evaluations of generation efficiency and fuel use remain predominantly theoretical. The stability of fuel supply is not solely a technical issue but a crucial factor in productive efficiency. Fluctuations in fuel availability influence generation output, marginal costs, and investment risk. Adegboyega and Odeyemi (2011) indicated over

ten years ago that gas shortages constrained Egbin's operations, and this issue continues to the present. The 2022 Egbin Power Plant Annual Report indicated that various grid system disruptions and gas supply deficiencies diminished output by 33%, decreasing from 642 MW in 2021 to 428 MW in 2022. Comprehending the extent and characteristics of these effects is crucial for formulating effective gas-to-power market frameworks. Empirical investigations at the plant level provide an essential connection between contractual supply agreements and actual economic performance. This study enhances the literature by offering plant-level empirical evidence regarding the correlation between natural gas supply and electricity generation efficiency, utilizing operational data from Egbin Power Plant, Nigeria's largest thermal power facility (Ogieva et al., 2015; Braide et al., 2021). The study measures the statistical correlation between actual gas offtake and power output, and assesses gas-to-power conversion efficiency measured in megawatts produced per unit of gas provided. The analysis clarifies the operational factors influencing generation performance under fuel supply restrictions by distinguishing the economic importance of actual fuel delivery in relation to scheduled supply metrics. The results provide three contributions to the field of energy economics study. The study offers strong empirical estimations of the gas-to-power conversion coefficient in actual operating settings. Secondly, it sets a pragmatic efficiency standard for assessing resource usage in gas-fired plants operating under fuel-constrained conditions. Third, it offers policy-relevant information into the economic ramifications of fuel supply unpredictability in nascent electrical markets.

## 2. REVIEW OF LITERATURE

### 2.1. Dependability of Fuel Supply and Energy Production

The reliability of fuel supply is a crucial factor influencing performance in thermal power systems. Deficiencies in natural gas result in diminished power generation (Abu et al., 2023). The Egbin plant, with an installed capacity of 1,320 MW, may function at reduced capacity, occasionally as low as 50-60% of its capability, due to fuel supply constraints (Ogieva et al., 2015; Adegboyega and Odeyemi 2011). This results in frequent power outages and load shedding, adversely affecting the Nigerian populace and enterprises reliant on the national grid (Renon Power Afrique, 2023). Fluctuations in fuel availability also create operational inefficiencies and modify marginal generation costs. In gas-fired systems, supply interruptions are especially significant due to the restricted on-site storage capacity of natural gas relative to other fossil fuels. As a result, generating output is significantly affected by the integrity of the upstream supply chain. Empirical investigations have consistently demonstrated that fuel supply limits disrupt generation planning and system reliability. Braide et al. (2021) highlight that unpredictability in gas supply substantially influences investment choices and the efficiency of plant dispatch, especially in emerging energy markets. Arthur and Asiedu-Okantah (2021) contended that infrastructure constraints and contractual inflexibilities exacerbate supply risks, thus influencing electricity market results. The International Energy Agency (IEA) analysis indicates that nations with efficient natural gas supply systems achieve superior economic growth and industrialization relative to those facing supply instability (IEA, 2025). In Nigeria, deficient gas distribution networks, antiquated infrastructure, and insufficient government regulations persist in obstructing the optimal functioning of gas-fired power plants. Consequently, power generation continues to be unstable, impacting national productivity and economic growth. Research on electricity system development indicates that fluctuations in fuel supply directly lead to the underutilization of built capacity (Occhiali and Falchetta, 2018). Although generating assets are theoretically available, actual production often indicates fuel limits more than technological limitations.

### 2.2. Generation Efficiency and Resource Optimization

Generation efficiency is a crucial issue in energy economics since it directly influences production costs, system reliability, and resource distribution. Efficiency study generally assesses the efficacy of converting fuel inputs into electrical outputs, encompassing both technological and operational factors. In fuel-dependent power systems, actual efficiency is influenced by plant design, thermal performance, and fuel supply conditions. Inconsistencies in fuel delivery may force producing units to function at suboptimal load levels, diminish capacity utilization, and heighten operational disturbances, therefore reducing effective efficiency. These dynamics are especially pronounced in emerging electrical markets like Nigeria. Although the installed generation capacity is around 12 GW, actual electrical output has often averaged about one-third of this nominal capacity, mostly due to gas supply limits, grid instability, and maintenance constraints (Akanonu, 2019; Cervigni et al., 2018). The ongoing disparity between installed capacity and actual output highlights the significance of resource usage efficiency over mere capacity expansion. Nigeria's electricity consumption trends underscore systemic inefficiencies. Per capita energy consumption is among the lowest worldwide at 144 kWh, indicative of constrained demand due to unpredictable supply conditions (World Energy Council, 2018; Moss and Portelance, 2017). The extensive dependence on self-generation, approximated at almost 14 GW of small-scale diesel

and petrol generators, engenders further economic inefficiencies due to increased production costs and fuel redundancy (Olabode & Oluwabamise, 2022).

### 2.3. Limitations of Natural Gas in Emerging Energy Markets

Emerging economies frequently demonstrate structural inconsistencies in the consumption of natural gas. The quantity of resources does not inherently ensure reliable supply or productive efficiency (Nelson, 2015). Infrastructure constraints, contractual discrepancies, and regulatory ambiguity often diminish the economic viability of gas-fired generating. Nigeria exemplifies this paradox well recorded in literature. Notwithstanding significant gas reserves, ongoing supply problems persistently hinder electricity generation (Oyewunmi and Iwayemi, 2016). Previous research identifies these limitations as resulting from pipeline vandalism, insufficient infrastructure investment, and pricing distortions in the domestic gas market (Nelson, 2015). Also, Nigeria's natural gas sector exhibits a persistent imbalance between production and domestic utilization. Figure 1 demonstrates that gas production has historically outpaced consumption, especially from the early 2000s onward (Emodi, 2016). The disparity between production and consumption indicates that Nigeria's energy supply issues are not merely due to resource scarcity but are significantly associated with utilization and delivery limitations. Notwithstanding significant production increases, the availability of gas for domestic power generation is constrained by infrastructural obstacles, transmission losses, and supply chain inefficiencies. Macro-level analysis have revealed structural inefficiencies in Nigeria's gas-to-power value chain. Occhiali and Falchetta (2018) highlight that fuel supply instability substantially affects generation deficits, whereas Mohammad et al. (2021) report inconsistencies between installed capacity and actual generation results. Nevertheless, a significant portion of this literature continues to concentrate on sectoral or national aggregates.

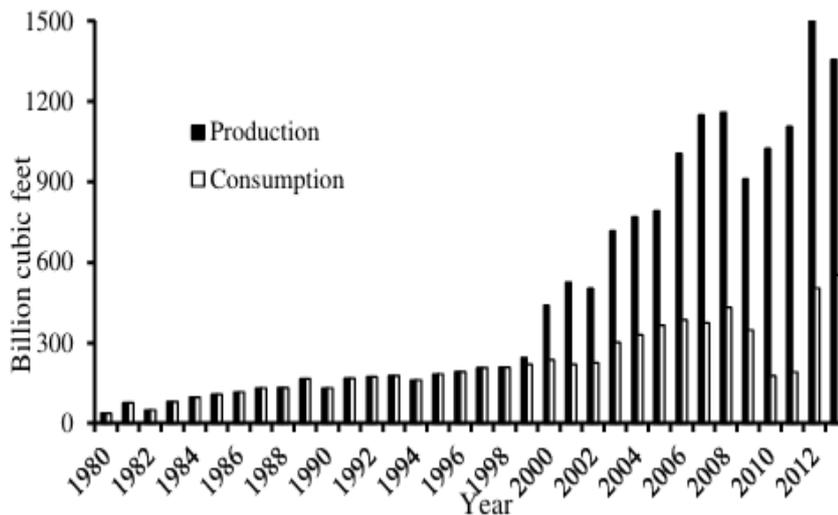


Figure 1: Gas production and consumption in Nigeria (Emodi, 2016).

### 2.4. Research Gap: Absence of Plant-Level Empirical Evidence

Existing literature has extensively examined the role of natural gas in electricity generation, fuel supply constraints, and their implications for power system performance. Prior studies within Nigeria largely emphasize sector-wide challenges, including infrastructural limitations, gas utilization inefficiencies, and operational disruptions (Ogieva *et al.*, 2015; Ekpu and Obadina, 2020). These supply variability affects generation outcomes at the plant level. Studies focusing on Egbin Power Plant have primarily concentrated on technical performance indicators such as forced outages, maintenance regimes, and equipment availability (Ogieva *et al.*, 2015). While gas supply inconsistencies are frequently acknowledged, the quantitative relationship between realized gas volumes and electricity output remains insufficiently explored. Beyond Nigeria, international studies highlight the vulnerability of gas-fired generation to supply chain disruptions, contractual arrangements, and infrastructure constraints (Shahidehpour *et al.*, 2005; Freeman *et al.*, 2020). However, differences in market structures, regulatory environments, and technological configurations limit the direct applicability of these findings to Nigeria's fuel-constrained electricity system. This study addresses this gap by providing localized empirical evidence from Egbin Power Plant, explicitly quantifying the relationship between gas supply variables and electricity generation performance analyses provide valuable

macro-level insights but offer limited empirical evidence on how fuel.

### 3. METHODOLOGY

#### 3.1 Research Design

This study adopts a quantitative empirical framework to examine the relationship between natural gas supply dynamics and electricity generation performance. The analysis is conducted at the plant level using operational data from Egbin Power Plant, Nigeria's largest gas-fired thermal facility. The selection of a quantitative approach is guided by the type of data at hand, which comprises numerical operational metrics like gas nomination, allocation, actual offtake, and related electrical output measured in megawatts (MW).

#### 3.2 Study Area and Data Description

The empirical analysis is conducted using operational data from the Egbin Thermal Power Station, located in Egbin, Ikorodu, Lagos State, Nigeria. Egbin is the largest gas-fired thermal power plant in Nigeria and represents a critical asset within the national electricity grid. Commissioned in 1985, the plant consists of six steam turbines with a combined installed capacity of 1,320 MW. The facility relies primarily on natural gas supplied through the Escravos-Lagos Pipeline System (ELPS).

The study utilizes plant-level operational data covering a 30-month period from January 1, 2023 to June 30, 2025. The dataset consists of daily observations capturing key fuel supply indicators and corresponding electricity generation outcomes. Variables include gas nomination volumes, gas allocation levels, actual gas offtake, and realized power output measured in megawatts (MW).

#### 3.3 Data Sources and Collection Procedures

This study utilizes a combination of plant-level operational records and contextual qualitative insights. The primary dataset consists of daily operational data obtained from Egbin Power Plant, capturing key natural gas supply indicators and corresponding electricity generation outcomes.

Operational data were derived from control room logs, daily performance reports, and gas metering records. These sources provide direct measurements of gas nomination volumes, scheduled allocations, actual gas offtake, and realized power output. The reliance on official plant records ensures measurement accuracy and consistency in fuel and generation variables.

To complement the quantitative dataset, structured consultations were conducted with technical personnel involved in plant operations and gas logistics management. These discussions provided contextual understanding of operational adjustments, fuel supply constraints, and system response mechanisms during periods of gas variability. Such qualitative inputs support interpretation of empirical results without altering the statistical structure of the analysis.

The dataset includes the following variables:

- **Date** – Observation period identifier
- **Gas Nomination (MMSCFD)** – Requested gas volume
- **Gas Allocation (MMSCFD)** – Scheduled supply volume
- **Actual Gas Offtake (MMSCFD)** – Realized fuel input
- **Power Output (MW)** – Electricity generation outcome

#### 3.4 Methods of Data Analysis

##### 3.4.1 Model Framework

The primary analytical model employed in this study is Multiple Linear Regression (MLR), implemented in IBM SPSS Statistics. MLR is selected for its suitability in predicting a continuous outcome variable, Power Output (MW), based on multiple continuous predictors: Gas Nomination, Gas Allocation, and Actual Offtake.

The MLR model is expressed as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \epsilon \dots\dots\dots (1)$$

Where:

- $Y$ : Power Output (MW)
- $X_1, X_2, X_3$ : Gas Nomination, Gas Allocation, and Actual Offtake, respectively

- $\beta_0$ : Intercept (baseline power output when all predictors are zero)
- $\beta_1, \beta_2, \beta_3$ : Regression coefficients for each predictor
- $\epsilon$ : Error term (unexplained variability)

### 3.4.2 Descriptive Statistics

Summary statistics mean, median, standard deviation, minimum, maximum, skewness, and kurtosis, was computed using SPSS’s descriptives procedure. These metrics describe the central tendency, dispersion, and distributional shape of Gas Nomination, Allocation, Offtake, and Power Output, flagging outliers or non-normality.

### 3.4.3 Correlation Analysis

Pearson’s correlation coefficient was calculated using SPSS’s Bivariate Correlation procedure to assess linear relationships, particularly between Actual Offtake and Power Output, and among predictors. The coefficient is given by:

$$r = \frac{\sum_{i=1}^n (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^n (X_i - \bar{X})^2 \sum_{i=1}^n (Y_i - \bar{Y})^2}} \dots\dots\dots (2)$$

The result of the correlation was visualized using scatter plot to better understand the relationships.

## 4. RESULT AND DISCUSSION

### 4.1 Descriptive Statistics

Table 4.1 presents descriptive statistics for gas nomination, allocation, actual offtake, and power output over the 30-month observation period. The results show that the mean gas nomination volume was 4546.57 MMSCFD, while the average allocation volume was 4327.28 MMSCFD. Actual gas offtake, representing realized fuel input, averaged 4204.14 MMSCFD. The corresponding mean electricity generation was 15,616.25 MW. The observed differences between nominated, allocated, and realized gas volumes indicate persistent deviations within the fuel supply chain. On average, actual gas deliveries fell below both nominated and allocated volumes, suggesting the presence of systematic supply constraints.

Measures of dispersion reveal notable variability across all variables. Standard deviations for the gas supply indicators, ranging between 679.90 and 755.88, indicate moderate fluctuations in fuel availability. Electricity output exhibited substantial variability ( $SD = 3078.94$ ), reflecting the operational sensitivity of generation outcomes. The minimum and maximum values further highlight the extent of variability. Actual gas offtake ranged from 2370.39 MMSCFD to 5473.78 MMSCFD, while power output varied from 8535.37 MW to 21,888.48 MW. These wide ranges underscore the presence of significant supply and performance volatility. From an economic perspective, variability in realized fuel input constitutes a critical driver of productive efficiency. Fluctuations in gas availability of this magnitude are likely to induce deviations from optimal operating conditions, reduce capacity utilization, and generate output instability.

Moreover, the substantial variation observed in electricity generation relative to fuel supply variability suggests that gas availability functions as a binding operational constraint. Such patterns are consistent with fuel-constrained production environments documented in electricity markets characterized by supply chain instability (Joskow, 2011; Newbery, 2018).

**Table 4.1: Descriptive Statistics of Gas Supply Variables and Power Output**

Variable	Mean	Std. Dev.	Min	25%	Median	75%	Max
Nomination (MMSCFD)	4546.57	689.61	3070.00	3963.25	4514.50	5157.00	6044.50
Allocation (MMSCFD)	4327.28	679.90	2220.41	3919.57	4377.35	4807.07	5675.50
Offtake (MMSCFD)	4204.14	755.88	2370.39	3605.18	4245.92	4717.78	5473.78
Power Output (MW)	15616.25	3078.94	8535.37	12981.63	15690.57	17856.78	21888.48

### 4.2 Correlation Analysis

Pearson correlation coefficients were computed to evaluate the strength and direction of the linear relationships between gas supply indicators and electricity generation. The results are presented in Table 4.2. The analysis reveals that actual gas offtake exhibits the strongest positive correlation with power output ( $r = 0.968$ ), indicating a near-perfect linear association between realized fuel input and electricity generation. This result suggests that variations in generation performance closely track fluctuations in physically delivered gas volumes.

Gas nomination ( $r = 0.888$ ) and allocation volumes ( $r = 0.911$ ) also display positive correlations with power output. However, the comparatively lower magnitudes indicate weaker predictive strength relative to actual offtake. These findings highlight an important operational distinction: while nominations and allocations represent contractual intentions and scheduling mechanisms, they do not necessarily translate into realized generation outcomes unless converted into physical fuel delivery. From a production economics perspective, the dominance of actual offtake reflects the central role of realized variable inputs in determining output. Electricity generation in gas-fired plants is inherently constrained by physically available fuel rather than contractual supply indicators.

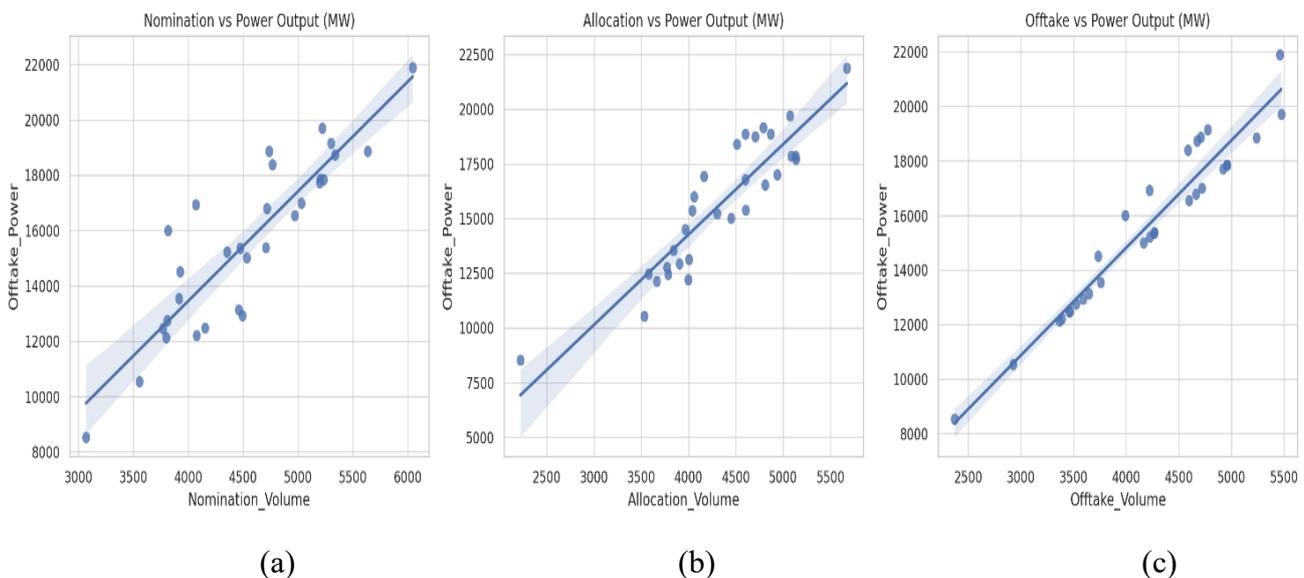
**Table 4.2: Correlation Matrix of Gas Supply Variables and Power Output**

Variables	Nomination	Allocation	Offtake	Power Output
Nomination (MMSCFD)	1.000	0.925	0.924	0.888
Allocation (MMSCFD)	0.925	1.000	0.950	0.911
Offtake (MMSCFD)	0.924	0.950	1.000	0.968
Power Output (MW)	0.888	0.911	0.968	1.000

### 4.3 Scatter Plot Analysis

The scatter plots presented in Figure 2 provide further visual confirmation of these relationships. The Offtake–Power Output relationship (c) exhibits a pronounced linear pattern with minimal dispersion, reinforcing the strong statistical association observed in the correlation analysis. In contrast, the Nomination–Output and Allocation–Output (a & b) relationships display greater variability around the fitted trend line, indicating weaker alignment between scheduled gas volumes and realized generation performance.

This divergence underscores the economic significance of supply chain execution. Deviations between planned and realized fuel inputs introduce uncertainty into generation outcomes, potentially affecting operational efficiency and capacity utilization.



**Figure 2: Scatter Plots of Gas Supply Variables Vs Power Output**

- a) Nomination vs Power Output
- b) Allocation vs Power Output
- c) Offtake vs Power Output

#### 4.4 Regression Results

The regression estimates provide quantitative evidence on the responsiveness of electricity generation to realized fuel input. Across alternative model specifications, the estimated coefficient for actual gas offtake ranged between 3.9 and 4.3. This implies that each additional unit of natural gas supplied (1 MMSCFD) increases electricity generation by approximately 4 MW. The stability of this coefficient across specifications indicates a consistent and predictable fuel-output relationship. The estimated coefficient represents the marginal productivity of natural gas in electricity generation. The magnitude confirms that realized fuel input functions as the dominant operational determinant of generation performance. This can be used by policymakers and operators to set realistic performance expectations and evaluate future upgrades

5. Conclusion  
This study offered actual evidence at the plant level about the correlation between natural gas supply dynamics and electricity generation performance, utilizing operational data from Egbin Power Plant, Nigeria's largest gas-fired thermal facility.

The results indicate a significant and statistically reliable correlation between electricity output and actual fuel input. Correlation and regression analyses consistently demonstrate that actual gas offtake is the primary determinant of generation performance, displaying a nearly perfect linear relationship with power output. The projected gas coefficient suggests that each supplementary unit of natural gas provided enhances electricity generation by roughly 4 MW, demonstrating a consistent and reliable fuel-output correlation. The results underscore a significant economic divergence between contractual supply metrics and actual operational inputs. Although gas nominations and allocations establish a scheduling framework, they do not consistently forecast generation results unless converted into actual fuel supply. Once actual gas offtake is considered, upstream supply factors become less significant, highlighting the importance of realized inputs in fuel-constrained production systems. The anticipated gas-to-power conversion ratio serves as a useful benchmark for assessing fuel productivity within the current Nigerian operational context. The relative consistency of this efficiency metric indicates that operational performance at the plant level is mostly limited by fuel availability rather than inherent conversion inefficiencies.

6. Policy Implications and Recommendations  
The research emphasizes that real gas delivery, as opposed to scheduled supply, is the primary factor influencing electricity generation in gas-reliant systems. This emphasizes the necessity for policies that prioritize the reliability of fuel supply, which includes fortifying pipeline infrastructure, minimizing operational disruptions, and improving coordination throughout the gas-to-power value chain. Enhancing fuel supply stability can yield rapid generation improvements without substantial investment in new capacity, rendering supply chain optimization a cost-effective approach for increasing system efficiency.

Structural discrepancies among nominated, allotted, and realized gas offtake indicate inefficiencies that can be rectified through enhanced regulatory monitoring, rigorous contractual enforcement, and transparent scheduling procedures. The projected gas-to-power conversion standard provides a tangible criterion for assessing plant performance and informing investment choices. Energy planning must include fuel supply concerns with conventional capacity evaluations to prevent the overestimation of effective generation capability. Targeted actions to enhance gas transport reliability and supply chain efficiency can substantially improve electricity generation stability and operational efficiency.

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Data availability

Daily operational data from Egbin power plant for 30 months were collected from the plant.

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