Assessing the Performance of a Gas Turbine Power Plant for Sustainable Electricity Supply in a Nigerian Faith-Based Community

Abstract

Nigeria's chronic electricity supply deficit has pushed many large institutions to develop captive, embedded generation to guarantee reliability, and religious camps that host very large periodic congregations are among the most demanding of such users. This study assesses the operational performance of a 25.8 MW captive gas turbine power plant — comprising three units, GT1 (5.2 MW), GT2 (5.6 MW) and GT3 (15 MW), fuelled by piped natural gas through a pressure-boosting system — that supplies the Redemption City of God (RCCG Redemption Camp), Ogun State, Nigeria, a faith-based community of more than 20,000 resident consumers that periodically hosts congregations exceeding two million people. Using sixteen months (January 2022–May 2023) of daily metered generation and consumption records obtained from the plant's 11 kV distribution control room, standard plant-performance indices were computed. The plant generated 39,655.51 MWh of energy in 2022 at an average load of 4.527 MW, giving a capacity factor of 17.55% and, using the single busiest metered day (12 August 2022, coinciding with the Annual Convention) as a proxy peak, a load factor of approximately 46.1% and a peak utilization factor of 38.0% of installed capacity. Transmission efficiency between the generating station and the 11 kV distribution point was high, at 96.4% in 2022, though it fell to 90.5% over January–May 2023, indicating an emerging area for monitoring. The results show that the plant is deliberately over-built relative to day-to-day demand, holding a reserve margin of about 62% to absorb infrequent but extreme event-driven peaks, a design logic distinct from the poor-maintenance-driven under-utilization reported for national utility-scale gas turbine plants in the literature. The study concludes that the captive plant provides a comparatively reliable, moderate-efficiency model of sustainable electricity supply for a faith-based community, and recommends structured availability/downtime logging, downstream metering reform to curb non-technical losses, and solar-hybridization of base-load to improve fuel efficiency and long-term sustainability.

Keywords: Gas Turbine Performance; Capacity Factor; Embedded Generation; Sustainable Electricity; Faith-Based Community; Redemption City; Nigeria

1. Introduction

Nigeria's national grid remains chronically unreliable: an estimated 43% of the population, more than 85 million people, lack access to grid electricity, and even connected consumers experience frequent outages driven by inadequate generation, transmission and distribution capacity (Zawya, 2025). This unreliability has been estimated to cost Nigerian businesses about $29 billion annually and has driven households and institutions to spend an estimated $22 billion a year on self-generation, overwhelmingly through diesel generators (Zawya, 2025; Energy for Growth Hub, 2023). The resulting "generator economy" is expensive, polluting, and reinforces continued underinvestment in grid infrastructure (Works in Progress, 2025; Energy Transition Africa, 2026).

In response, embedded (distributed) generation — power production connected directly to the distribution network rather than the high-voltage transmission grid — has emerged as a pragmatic interim strategy for reliable electricity supply in Nigeria (International Bar Association, 2023; Davidson, 2003). Embedded generation can supply standby and peak-shaving capacity, improve overall grid efficiency, and, where gas-fired, displace costlier and more polluting diesel self-generation (International Bar Association, 2023; Power Sector Reform in Nigeria, 2018). Nigeria's Electricity Act of 2023 has further strengthened the legal basis for state-level, private, and community electricity generation, explicitly encouraging embedded and decentralized generation models (RSC Sustainability, 2025).

Large religious institutions present an unusual and under-studied case of embedded generation demand. Faith-based communities that host mass gatherings combine a stable, moderate residential and institutional base load with extreme, short-duration peaks driven by periodic religious conventions and services that can draw crowds in the hundreds of thousands to millions (Starlett, 2013; The Redeemed Christian Church of God, 2022). The Redemption City of God (commonly called RCCG Redemption Camp), headquarters of the Redeemed Christian Church of God (RCCG) at kilometre 46 of the Lagos–Ibadan Expressway in Ogun State, Nigeria, is one of the largest such communities in the world (Obateru *et al.*, 2019; Oyediji, 2022). It spans more than 40,000 hectares, permanently houses over 20,000 metered consumers across more than 150 distribution substations (RCCG Electrical Generation and Distribution Department, 2021), and hosts a monthly all-night Holy Ghost Service attended by upward of 500,000 people, alongside an Annual Convention and a Holy Ghost Congress — each typically held in the first weeks of August and December respectively — that draw crowds in excess of two million, on infrastructure designed to eventually accommodate up to six million visitors (The Redeemed Christian Church of God, 2022; Starlett, 2013).

To meet this demand independently of the national grid, the camp operates a captive gas turbine power station of three synchronized units — GT1 (5.2 MW), GT2 (5.6 MW) and GT3 (15 MW) — with a combined installed capacity of 25.8 MW, fuelled by piped natural gas (PNG) delivered through a gas pressure-boosting system, generating at 11 kV and distributed through two incomer feeders serving nine outgoing 11 kV distribution feeders (Folorunso, 2024; RCCG Electrical Generation and Distribution Department, 2021). This is, in effect, a small independent power system serving a faith-based city.

While a substantial body of literature has assessed the performance of Nigeria's utility-scale gas turbine power stations — including Afam, Edjeba, Omotosho, and the AES Barge plant in Lagos — almost all such plants are reported to perform poorly against international benchmarks, with low availability attributed largely to inadequate gas supply, poor maintenance, and weak grid off-take arrangements (Ohunakin *et al.*, 2014; Ademusuru *et al.*, 2017; Adegboyega & Famoriji, 2013; Egware & Obanor, 2013; Oyedepo *et al.*, 2015). No comparable performance assessment has been published for a captive, faith-based-community-scale embedded gas turbine plant, whose load profile, ownership structure, and maintenance incentives differ materially from those of national utility IPPs. This study addresses that gap.

1.1 Aim and Objectives

This study aims to assess the operational performance of the Redemption City of God gas turbine power plant as a model of sustainable, embedded electricity supply for a large faith-based community. The specific objectives are to: (i) quantify the plant's monthly and annual energy generation and consumption pattern using metered operational data for January 2022–May 2023; (ii) compute standard plant-performance indices — capacity factor, load factor, utilization factor, reserve margin, and transmission efficiency; (iii) benchmark the computed indices against comparable Nigerian utility-scale gas turbine plants reported in the literature; and (iv) draw out the implications of the results for the long-term sustainability of embedded gas turbine generation in faith-based and similarly event-driven institutional communities.

1.2 Justification and Scope

The Redemption City power network has previously been studied from the standpoint of transmission and distribution power losses. This study is distinct and complementary: rather than examining where energy is lost after generation, it examines how well the generating plant itself is being utilized relative to its installed capacity, a question of central importance to the economic and environmental sustainability of any embedded power system. The scope covers the three gas turbine units and the 11 kV incomer/distribution interface only; downstream low-voltage distribution losses are referenced from the companion transmission-and-distribution study only where relevant to sustainability implications.

2. Literature Review

2.1 Gas Turbine Power Plants and Performance Indices

Gas turbine power plants convert the chemical energy of a fuel — typically natural gas — into mechanical and then electrical energy through the Brayton cycle, compressing air, combusting fuel, and expanding the hot gases through a turbine coupled to a generator (Grigsby *et al.*, 2006; Theraja & Theraja, 2008). Standard indices used to evaluate the operational performance of such plants include the capacity factor (actual energy generated over a period as a fraction of the energy that would be generated at full installed capacity for the same period), the load factor (average load as a fraction of peak load), the plant use factor and utilization factor (which relate energy generated to actual operating hours and to peak demand respectively), and the availability factor (the fraction of time the plant is capable of generating) (Oyedepo *et al*., 2015; Ohunakin et al., 2014). International benchmarks typically place an efficient plant's capacity factor between 50% and 80%, availability above 80–95%, and load factor around 80% (Oyedepo *et al.*, 2015).

2.2 Performance Assessment of Gas Turbine Plants in Nigeria

A substantial literature has assessed Nigerian utility-scale gas turbine plants against these benchmarks, almost uniformly finding severe underperformance. A study of a 301 MW (9 × 31.5 MW) gas turbine station in Lagos over 2001–2010 found only 64.3% of installed capacity available, a load factor between 20.8% and 78.2%, and an energy generation shortfall of about 35.7% of the target (Ohunakin *et al.*, 2014). A nine-year study of the Afam IV and V plant in the Niger Delta found only 12.01% of installed capacity available throughout the review period, with a capacity factor ranging from just 1.5% to 29.3% and a load factor averaging 41% (Ademusuru *et al.*, 2017). Similarly, an assessment of selected Nigerian gas turbine plants for 2006–2010 found capacity factors ranging from 16.88% to 73.67% and concluded that generating units were systematically underutilized owing to inadequate routine maintenance and equipment faults (Oyedepo *et al.*, 2015). A study of the Edjeba gas turbine plant in Delta State over 2002–2012 found a capacity factor of only 20.4% against an ISO target of 40–65% (Adegboyega & Famoriji, 2013). More recent work covering an eight-unit gas turbine plant in south-western Nigeria for 2016–2022 found capacity factors of 21.81%–51.70% and utilization factors of 67.51%–74.95%, still short of the 95% international benchmark (Global Scientific Journal, 2023). Across this literature, poor gas supply, inadequate maintenance, weak spare-parts inventory, and grid off-take constraints are the recurring explanations for underperformance, rather than any inherent limitation of gas turbine technology (Oyedepo *et al.*, 2015; Ademusuru *et al.*, 2017).

2.3 Thermodynamic (Energy–Exergy) Performance Approaches

A parallel body of work evaluates gas turbine performance thermodynamically rather than statistically. Energy–exergy analysis of a 5.67 MW gas turbine plant serving an oil-industry office complex in Port Harcourt used first- and second-law analysis to identify inefficiencies in the compressor, combustion chamber and turbine (IJRASET, 2023). Exergy studies of gas turbine cycles in Oman and Egypt report combustion-chamber exergy destruction as the dominant source of thermodynamic loss, with overall plant exergy efficiencies typically in the 27–34% range (Sultan Qaboos University, 2017; Journal of Thermal Analysis and Calorimetry, 2024), while a study of a 125 MW gas turbine plant found an energy-based thermal efficiency of about 30.2%, with the bulk of energy loss carried away in the exhaust gases (ScienceDirect, 2025a). Waste-heat-recovery integration studies suggest that recovering this exhaust energy can raise exergetic efficiency substantially (Journal of Mechanical Engineering and Sciences, 2024), underscoring an important pathway for improving the fuel efficiency and sustainability of existing gas turbine assets rather than simply expanding installed capacity (Tandfonline/Engineering Applications of Computational Fluid Dynamics, 2024).

2.4 Embedded and Distributed Generation in Nigeria

Embedded generation — generation connected directly to the distribution network rather than the high-voltage transmission grid — has been identified as a practical near-term strategy for improving electricity reliability in Nigeria, given persistent transmission and generation constraints on the national grid (International Bar Association, 2023; Davidson, 2003). It can provide standby power, peak-shaving capability, and cogeneration, improving overall network efficiency by adding multiple micro-sources close to the point of use (International Bar Association, 2023; Power Sector Reform in Nigeria, 2018). Analysis by RMI and Lion's Head Global Partners estimates that embedded generation projects, if scaled with Nigerian electricity distribution companies, could contribute up to 5 GW of supply, displacing a significant share of the 14–42 GW of diesel self-generation capacity estimated to exist in the country (RMI & Lion's Head Global Partners, 2023; RMI, 2025). Nigeria's Electricity Act of 2023 has reinforced this direction by decentralizing licensing authority to sub-national governments and explicitly encouraging embedded and off-grid generation, including in rural and underserved communities (RSC Sustainability, 2025). Broader assessments of Nigeria's power sector reliability likewise find that improving plant availability — rather than solely expanding installed capacity — is central to meeting the country's decarbonization and energy-access targets (ScienceDirect, 2025b).

2.5 Sustainable Electricity in Faith-Based and Event-Driven Communities

The Redemption City of God is documented in the literature primarily from historical, ecological and infrastructural perspectives rather than from an energy-systems perspective. It is described as the headquarters and largest campground of the Redeemed Christian Church of God, a denomination with more than 10 million members across over 15,000 parishes worldwide, occupying over 40,000 hectares and hosting an all-night Holy Ghost Service on the first Friday of every month, in addition to an Annual Convention and Holy Ghost Congress each drawing multi-million crowds (The Redeemed Christian Church of God, 2022; Starlett, 2013; Oyediji, 2022). Ecological survey work conducted within the camp

(Loburo Forest) further situates it as a large, semi-urbanized institutional settlement rather than a conventional residential township (Obateru *et al.*, 2019). The camp's own distribution network — comprising approximately 150 substations, nine 11 kV feeders, and more than 20,000 consumers — has previously been examined from a transmission-and-distribution power-loss perspective, which found the network's transmission stage to be efficient but its downstream distribution stage to suffer very high non-technical losses (Folorunso, 2024). This combination of a large permanent population with extreme, calendar-driven attendance peaks creates a load profile that differs materially from both a typical utility grid and a typical industrial captive plant, yet, to date, no published study has quantitatively assessed the performance of the gas turbine plant that powers it.

2.6 Research Gap

The reviewed literature establishes two things clearly: first, those Nigerian utility-scale gas turbine plants are, almost without exception, severely underutilized relative to international benchmarks, primarily because of gas-supply, maintenance, and grid-integration constraints; and second, embedded generation — including gas turbine-based embedded generation — is an actively promoted policy solution to Nigeria's electricity reliability crisis. However, no study has examined how a captive, community-owned gas turbine plant serving a faith-based institution with an extreme, event-driven demand profile performs against the same indices used to assess national utility plants, nor how such a plant's performance profile should be interpreted differently given its distinct purpose and ownership structure. This study addresses that gap using operational metering data from the Redemption City of God gas turbine plant.

3. Materials and Methods

3.1 Study Area and Plant Description

The Redemption City of God (RCCG Redemption Camp) is located at kilometre 46 of the Lagos–Ibadan Expressway, in Loburo, Owode Local Government Area, Ogun State, Nigeria, bordered by Mowe and Loburo to the north, Sagamu Local Government to the south, Ikorodu (Lagos State) to the east, and Deeper Life Campground to the west (Obateru *et al.*, 2019). Founded in 1952 by Pa Josiah Akindayomi and expanded under Pastor Enoch Adejare Adeboye, the Redeemed Christian Church of God opened the campground in 1983; it has since grown into a self-contained faith-based city encompassing residential estates, banks, health centres, schools, and administrative offices, valued at over ₦200 billion and covering more than 40,000 hectares (The Redeemed Christian Church of God, 2022; Oyediji, 2022).

Figure1: Gas Turbine Power Generator GT1(5.2MW) and GT2(5.6MW)

Electricity for the camp is generated by three synchronized natural-gas turbines — GT1 (5.2 MW), GT2 (5.6 MW) and GT3 (15 MW) — giving a combined installed capacity of 25.8 MW (Folorunso, 2024).

Figure 2: Gas Turbine Power Generators GT3 15MW

Figure 3: Gas Booster

The turbines are fuelled by piped natural gas (PNG), whose pressure is raised through a gas pressure-boosting system (shown in Figure 3) prior to combustion; auxiliary operating parameters recorded during a site visit on 14 August 2023 included a water-jacket temperature of 42.5°C, gas inlet pressures of 12.9–15.9 barg, a gas outlet pressure of 27.4 barg, and an oil system pressure of 29.8 barg, indicating the plant was operating within normal thermal and hydraulic parameters at the time of inspection (Folorunso, 2024).

Figure 4: In comer feeder-2, 11KV Control panel and the six distribution feeders were installed.

There are two incomer feeders, Incomer 1 and Incomer 2 (as shown in Figure 4) which deliver power to nine outgoing 11kV distribution feeders: Altar Complex, Prayer Foyer and IGH (11/33 kV, 7.5 MVA step-up transformers, served through Incomer 1 with power sourced from the new auditorium at Shimawa), and Run, Daddy G.O., Main Camp, Dormitory, Arena and Lotto (served through Incomer 2 with power from the main camp and arena) (RCCG Electrical

Generation and Distribution Department, 2021). The short underground route (approximately 150 m) from the turbines to the 11 kV distribution control room uses 2×150 mm² single-core 11 kV XLPE cable for GT1/GT2 and 2×300 mm² single-core 11 kV XLPE cable for GT3 to reduce the potential for corona discharge and line weather losses that are typical of long overhead lines (Folorunso, 2024). The distribution network consists of about 150 substations, totaling about 100MVA installed capacity that supply over 20,000 metered and unmetered consumers, according to the RCCG Electrical Generation and Distribution Department (2021).

3.2 Data Collection

The RCCG Electrical Generation and Distribution Services Department metering records were used to obtain total energy readings from the turbines and total energy consumed at each of the nine outgoing feeders every day for sixteen (16) months starting from January 2022 through May 2023 (RCCG Electrical Generation and Distribution Department, 2022). The monthly aggregates were cross-checked for 2022 with the daily metering spreadsheets maintained by the Department, and the dis-aggregation by feeders for December 2022 was not completed in the source records, so the dis-aggregation is shown by the whole network for that month only. The operating parameters of the auxiliary gas-booster were recorded through an inspection of the generating station and 11 kV distribution control room (Folorunso, 2024).

3.3 Performance Indices

The following standard indices were computed for the plant, consistent with established practice in the Nigerian gas turbine performance literature (Oyedepo *et al.*, 2015; Ohunakin *et al.*, 2014; Ademusuru *et al*., 2017):

$$\text{Capacity Factor (CF)} = [\, Ea / (Cinstalled \times T) \,] \times 100 \tag{1}$$

where Ea is the actual energy generated (MWh) over period T (hours), and Cinstalled is the installed plant capacity (25.8 MW).

$$\text{Average Load} = Ea / T \tag{2}$$

$$\text{Load Factor (LF)} = (\text{Average Load} / \text{Peak Load}) \times 100 \tag{3}$$

Peak load was approximated from the single highest-output metered day within the study period (an accepted proxy where sub-daily telemetry is unavailable, consistent with monthly-resolution approaches used in prior Nigerian gas turbine performance studies), divided by 24 hours.

$$\text{Utilization Factor} = (\text{Peak Load} / Cinstalled) \times 100 \tag{4}$$

$$\text{Reserve Margin} = Cinstalled - \text{Peak Load} \tag{5}$$

$$\text{Transmission Efficiency } (\eta) = (Er / Eg) \times 100 \tag{6}$$

where Eg is the energy generated at the turbine and Er is the energy received at the 11 kV distribution control room, consistent with the differential energy-loss method used in the companion distribution-loss study of this same network (Folorunso, 2024). Because structured outage/downtime logs were not available for the study period, the plant use factor and availability factor could not be independently computed; the near-continuous presence of metered generation on every day of the review period was instead taken as evidence that the plant operated close to continuously, so that the plant use factor is closely approximated by the capacity factor reported here. This is stated explicitly as a limitation of the study.

4. Results and Discussion

4.1 Monthly Energy Generation and Consumption, 2022

Table 1 presents the monthly energy recorded from the turbines and the corresponding energy consumed at the 11 kV distribution point for January–December 2022, converted to megawatt-hours (MWh) (RCCG Electrical Generation and Distribution Department, 2022; Folorunso, 2024).

Month	Energy Generated (MWh)	Energy Consumed (MWh)	Received/Generated (%)
January	3676.60	3551.00	96.58
February	2338.11	2275.00	97.30
March	3894.07	3793.00	97.40
April	3905.56	3755.00	96.14
May	2689.19	2605.50	96.89
June	2907.39	2809.00	96.62
July	2351.42	2219.30	94.38
August	4041.15	3885.50	96.15
September	2965.62	2900.70	97.81
October	3054.49	2964.30	97.05
November	3912.24	3801.15	97.16
December	3919.67	3682.35	93.95
TOTAL	39655.51	38241.80	96.44

Table 1. Monthly energy generated and consumed, Redemption City gas turbine plant, 2022. Source: RCCG Electrical Generation and Distribution Services Department metering records.

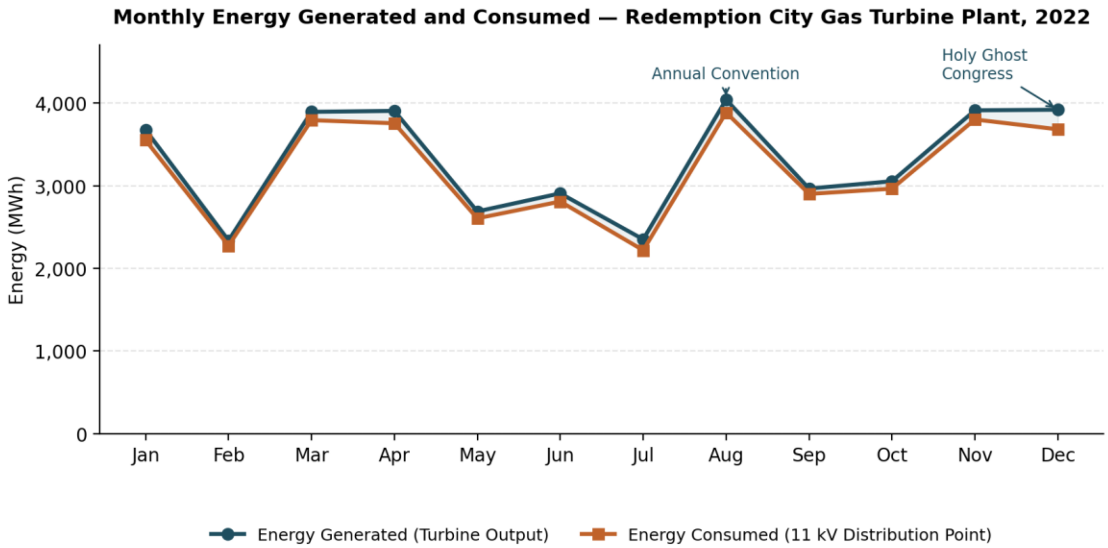

Figure 5. Monthly energy generated and consumed, 2022. The gap between the two curves represents transmission-stage loss; the sharpest peaks in August and December coincide with the Annual Convention and Holy Ghost Congress.

Over 2022 the plant generated a total of 39,655.51 MWh, of which 38,241.80 MWh (96.4%) was received at the 11 kV distribution point. Generation tracked demand closely throughout the year, with the two highest-generation months — August (4,041.15 MWh) and December (3,919.67 MWh) — coinciding with the Annual Convention and Holy Ghost Congress respectively, and the lowest generation occurring in February (2,338.11 MWh), a shorter month with no major mass event. This confirms that the camp's event calendar, rather than seasonal weather variation, is the dominant driver of monthly demand variability.

4.2 Feeder-Wise Load Distribution

Table 2 summarizes cumulative energy consumption by feeder for January–November 2022 (the period for which complete feeder-level disaggregation was available in the source metering records) (RCCG Electrical Generation and Distribution Department, 2022).

Feeder	Incomer	Energy Consumed, Jan–Nov 2022 (MWh)	Share of Total (%)
Run	Incomer 2	4240.00	12.2
Daddy G.O.	Incomer 2	6075.00	17.5
Main Camp	Incomer 2	4042.00	11.6
Dormitory	Incomer 2	4323.00	12.4
Arena	Incomer 2	5677.00	16.3
Lotto	Incomer 2	6792.00	19.5

Feeder	Incomer	Energy Consumed, Jan–Nov 2022 (MWh)	Share of Total (%)
Altar Complex	Incomer 1	1786.00	5.1
Prayer Foyer	Incomer 1	1487.00	4.3
IGH	Incomer 1	359.90	1.0
TOTAL	—	34781.90	100.0

Table 2. Feeder-wise energy consumption, January–November 2022 (December feeder-level data incomplete in source records).

The Lotto and Daddy G.O. feeders were the two largest loads on the network, together accounting for over a third of total distributed energy, followed by the Arena feeder, which serves the main congregation ground and experiences the sharpest event-driven peaks. The Incomer 1 feeders (Altar Complex, Prayer Foyer, IGH), which serve the newer 3 km by 3 km auditorium complex at Shimawa, together drew markedly less energy than the Incomer 2 feeders serving the older main camp, consistent with the Shimawa auditorium complex being used mainly for the twice-yearly Convention and Congress rather than daily camp operations.

4.3 Plant Performance Indices

Using the installed capacity of 25.8 MW and 8,760 hours in 2022, and applying Equation (1), the plant's capacity factor was:

$$CF = 39{,}655.51 / (25.8 \times 8{,}760) \times 100 = 17.55\% \quad (7)$$

The corresponding average load over the year was 4.527 MW. The single highest-output metered day in the study period was 12 August 2022 — within the week of the Annual Convention — with 235.524 MWh generated, equivalent to an average load of 9.813 MW over that day. Using this as a peak-load proxy in Equations (3) and (4):

$$LF = 4.527 / 9.813 \times 100 = 46.1\% \qquad \text{Utilization Factor} = 9.813 / 25.8 \times 100 = 38.0\% \quad (8)$$

The plant therefore carried a reserve margin of approximately 15.99 MW, or about 62.0% of installed capacity, even on its busiest recorded day. Table 3 places these results alongside comparable Nigerian utility-scale gas turbine plants reported in the literature.

Plant / Study	Installed Capacity	Capacity Factor (%)	Load Factor (%)	Availability (%)	Source
Redemption City GT plant	25.8 MW	17.6	46.1	not logged	This study, 2022
AES Barge, Lagos (2001–2010)	301 MW (9×31.5 MW)	20.8–78.2	20.8–78.2	64.3	Ohunakin *et al.*, 2014

Plant / Study	Installed Capacity	Capacity Factor (%)	Load Factor (%)	Availability (%)	Source
Afam IV & V, Niger Delta	—	1.5–29.3	41 (avg.)	12.0	Ademusuru *et al.*, 2017
Selected Nigerian GT plants (2006–2010)	—	16.9–73.7	—	—	Oyedepo *et al.*, 2015
Edjeba GT plant, Delta State (2002–2012)	—	20.4	81.8	—	Adegboyega & Famoriji, 2013
Eight-unit GT plant, SW Nigeria (2016–2022)	—	21.8–51.7	—	67.5–75.0 (utilization)	Global Scientific Journal, 2023

Table 3. Comparison of computed performance indices with Nigerian utility-scale gas turbine plants reported in the literature.

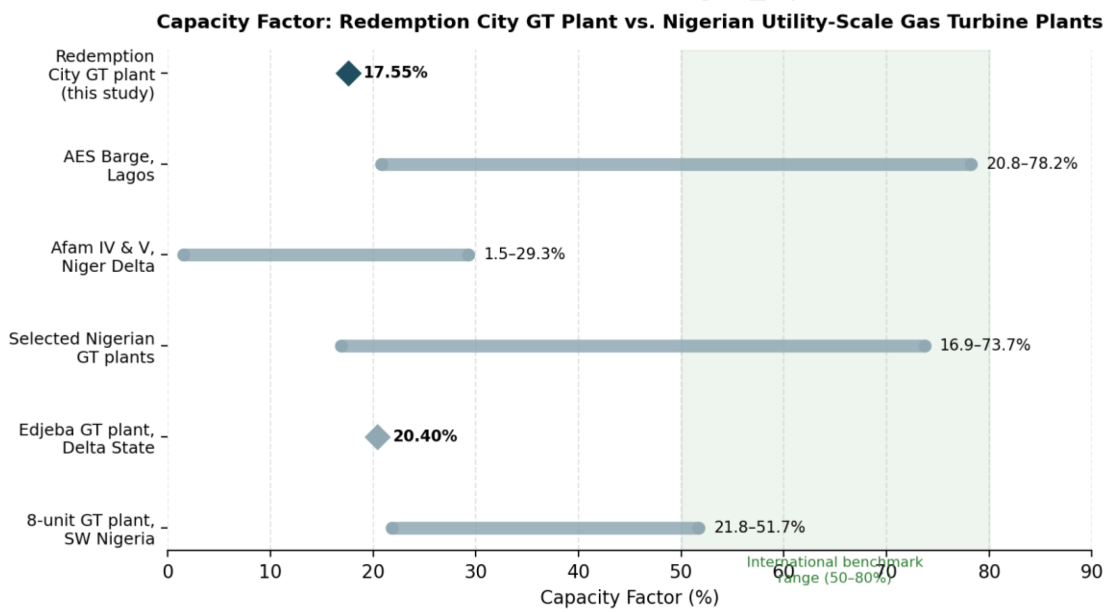

Figure 2. Capacity factor of the Redemption City plant against the range reported for Nigerian utility-scale gas turbine plants in the literature, relative to the 50–80% international benchmark band.

The Redemption City plant's capacity factor (17.6%) falls within the low range reported across the national literature, but its load factor (46.1%) is comparatively favourable, exceeding the Afam plant's average of 41% (Ademusuru *et al.*, 2017) and sitting within the wide range reported for the AES Barge plant (Ohunakin *et al.*, 2014). Critically, however, the interpretation differs: whereas the reviewed utility-scale studies attribute low capacity factors chiefly to inadequate gas supply, poor maintenance, and weak grid off-take arrangements outside the operator's control (Oyedepo *et al.*, 2015; Ademusuru *et al.*, 2017), the Redemption City plant's low capacity factor appears to reflect a deliberate design decision to size the plant for rare, extreme, multi-million-attendee events rather than routine daily demand. A 25.8 MW plant sized to the camp's typical 4.5 MW average load would be considered heavily over-built by conventional utility-planning standards, but is a reasonable and arguably necessary reliability margin for an institution whose demand can spike sharply during a Convention or Congress week.

4.4 Transmission Efficiency and Losses

Energy received at the 11 kV distribution control room as a share of energy generated at the turbines was 96.4% in 2022, corresponding to a transmission loss of 3.6% (1,413.71 MWh) between the generators and the distribution point, consistent with the 97% transmission efficiency independently reported for this same network by Folorunso (2024). This compares favourably with the technical loss range of 22.5%–25% typically reported for Nigerian distribution networks more broadly (Anumaka, 2012; Akpojedje, 2017), and is attributable to the short (approximately 150 m), underground, XLPE-cabled connection between the turbines and the control room, which is largely immune to the corona and weather-related losses that affect long overhead transmission lines (Folorunso, 2024). For the five months of 2023 with available data (January–May), however, the received share fell to 90.5%, a loss of 9.5%. While this remains within internationally cited technical-loss ranges, the year-on-year increase — alongside a higher average load of 5.267 MW over the same five months in 2023 compared with 4.527 MW for the whole of 2022 — suggests that rising demand may be placing additional strain on plant and cabling infrastructure, and warrants closer monitoring in subsequent reporting periods.

The wider literature on power losses in African and Nigerian distribution networks provides useful context for interpreting this result. Transmission and distribution losses are generally defined as the difference between the energy injected into a network and the energy billed to end users (Ajmal Ismail, 2022; Bhalla, 2000), and are typically decomposed into unavoidable technical losses arising from conductor resistance, transformer core losses and reactive effects, and non-technical (commercial) losses arising from theft, unmetered connections and billing inefficiencies (Jagdeep, 2018; Komolafe & Udofia, 2020). Case studies of Nigerian 11–33 kV distribution feeders in Ekpoma, Edo State (Gabriel & Franklin, 2014) and Uyo, Akwa Ibom State (Nta, 2022) report technical losses broadly consistent with the 3.6% transmission-stage loss found for the Redemption City plant, while studies of South African municipal networks (Khonjelwayo & Nthakheni, 2021) and Ugandan 132–220 kV transmission lines (Living *et al.*, 2023) similarly attribute the larger share of total network losses to the distribution rather than the transmission stage, mirroring the pattern reported for this same network by Folorunso (2024). Network reconfiguration and loss-reduction optimization methods proposed elsewhere (Pegado *et al.*, 2019; Xie *et al.*, 2021) offer potential approaches for addressing the downstream losses that limit the overall sustainability benefit of the Redemption City plant's otherwise efficient generation and transmission performance.

4.5 Event-Driven Load Variability

The data confirm that the camp's electricity demand is structured around its religious calendar rather than conventional seasonal or industrial demand cycles. August and December, hosting the Annual Convention and Holy Ghost Congress respectively, were consistently the two highest-generation months of 2022, and the single highest-output day in the entire study period fell within the August Convention week (The Redeemed Christian Church of God, 2022). The monthly all-night Holy Ghost Service, held on the first Friday of every month, produces a smaller but recurring monthly peak (Starlett, 2013; The Redeemed Christian Church of God, 2022). This event-driven variability is the principal justification for the plant's substantial reserve margin: unlike a conventional industrial or municipal load, which grows gradually and can be forecast for incremental capacity expansion, the Redemption City load can multiply many times over within a single week each year, and the generating capacity must be available at that scale on demand.

4.6 Implications for Sustainable Electricity Supply in Faith-Based Communities

Three implications follow for the long-term sustainability of embedded gas turbine generation in faith-based and similarly event-driven institutional communities. First, the captive gas turbine model demonstrably provides a level of reliability substantially higher than dependence on Nigeria's national grid, and, being fuelled by piped natural gas rather than diesel, avoids the high per-kWh cost and local emissions associated with diesel self-generation, consistent with the direction encouraged by Nigeria's Electricity Act of 2023 and by wider embedded-generation policy analysis (RSC Sustainability, 2025; RMI & Lion's Head Global Partners, 2023; The Energy for Growth Hub, 2023). Second, a low capacity factor should not, in this context, be read as evidence of poor plant management, as it typically is in utility-scale assessments (cf. Oyedepo *et al.*, 2015; Ademusuru *et al.*, 2017); rather, it reflects the intentional sizing of the plant for rare extreme events, and future assessments should therefore report both an annual capacity factor and an event-week utilization figure to avoid mischaracterizing deliberately reserved capacity as waste. Third, sustainability is nonetheless constrained by two factors documented in this and the companion distribution-loss study of the same network (Folorunso, 2024): the absence of structured plant availability/downtime logging, which prevented computation of a true availability factor in this study, and substantial non-technical losses reported downstream in the 11 kV distribution network, which reduce the overall benefit of efficient generation and transmission. Hybridizing baseload demand with solar photovoltaic generation — feasible given the camp's daytime institutional load and Nigeria's solar resource — could reduce gas consumption and running hours on the smaller turbines during non-event periods, improving fuel efficiency without compromising the reserve capacity retained for mass events (Frontiers in Energy Research, 2024; Journal of Mechanical Engineering and Sciences, 2024).

5. Conclusion and Recommendations

5.1 Conclusion

This study assessed the operational performance of the 25.8 MW captive gas turbine plant supplying the Redemption City of God, a faith-based community in Ogun State, Nigeria, using sixteen months of metered generation and consumption data. The plant generated 39,655.51 MWh in 2022 at a capacity factor of 17.55%, a load factor of approximately 46.1%, and a peak utilization factor of 38.0% of installed capacity, carrying a reserve margin of about 62% even on its busiest recorded day. Transmission efficiency between the turbines and the 11 kV distribution point was high at 96.4% in 2022, though it declined to 90.5% over January–May 2023. While the plant's capacity factor sits within the low range reported for Nigerian utility-scale gas turbine plants, its load factor compares favourably, and its low capacity factor is best understood as a deliberate reliability margin for the extreme, event-driven peaks generated by the camp's Annual Convention and Holy Ghost Congress rather than as evidence of under-performance. The captive gas turbine model represents a comparatively reliable and reasonably efficient approach to sustainable electricity supply for a large faith-based community operating independently of Nigeria's national grid.

5.2 Recommendations

- Structured plant availability and downtime logging should be introduced for all three turbines, to enable computation of a true availability factor and to support proactive, rather than reactive, maintenance scheduling.
- Transmission and cabling infrastructure between the generating station and the 11 kV distribution control room should be inspected in light of the declining received-energy share observed between 2022 and early 2023, before losses grow further.
- Performance reporting for event-driven embedded plants of this kind should present both an annual capacity factor and an event-week utilization figure, so that deliberately reserved capacity is not mischaracterized as inefficiency.
- A feasibility study of solar photovoltaic hybridization for daytime institutional and residential baseload should be conducted, to reduce gas consumption and running hours on the smaller turbines outside major event periods.
- Downstream metering and billing reforms identified in the companion distribution-loss study of this same network should be pursued in parallel, since even highly efficient generation and transmission cannot deliver full sustainability benefits if a large share of distributed energy remains unmetered or unbilled.

5.3 Contribution to Knowledge

This study provides the first published performance assessment, using standard plant-performance indices, of a captive gas turbine plant serving a large faith-based community in Nigeria, and proposes that such event-driven embedded plants be evaluated using both conventional annual indices and an event-week utilization measure that better reflects their intended design purpose.

Acknowledgments

The authors gratefully acknowledge the RCCG Electrical Generation and Distribution Services Department, Redemption City of God, for access to plant operational and metering records used in this study.

References

Adegboyega, G. A., & Famoriji, J. O. (2013). Reliability and performance evaluation of a gas turbine power plant: A case study of Edjeba gas turbine plant, Delta State, Nigeria. International Journal of Engineering and Technology.

Ademusuru, P. O., Ogunedo, M. B., & Okoro, V. I. (2017). Performance evaluation of gas turbine plant in Niger Delta region of Nigeria: A case study of Afam power plant. Elixir Mechanical Engineering, 108, 47419–47422.

Ajmal Ismail. (2022, March). What are losses in Electrical Power Systems?

Akpojedje, F. O. (2017). Causes and modeling of power losses on electric power distributors and its effects on household appliances in the Nigerian power distribution network. International Journal of Innovative Science, Engineering & Technology.

Anumaka, M. C. (2012). Analysis of technical losses in electrical power system (Nigerian 330kV network as a case study). International Journal of Research and Reviews in Applied Sciences, 12(2).

Bhalla, M. S. (2000). Transmission and distribution losses (power).

Davidson, I. E. (2003). Distributed generation in Nigeria's electricity industry deregulation. Journal of the SA Institute of Electrical Engineers.

Egware, H. O., & Obanor, A. I. (2013). Exergy analysis of Omotosho Phase 1 gas thermal power plant. Journal of Emerging Trends in Engineering and Applied Sciences.

Energy Transition Africa. (2026). Nigeria's $14 billion generator economy is blocking the transition.

Folorunso, A. O. (2024). Investigating the point of loading power losses on Redemption City power network, Ogun State, Nigeria [Master's dissertation, Bells University of Technology, Ota].

Frontiers in Energy Research. (2024). Technical, economic, and environmental feasibility assessment of solar-battery-generator hybrid energy systems: A case study in Nigeria.

Gabriel, A. A., & Franklin, O. (2014). Determination of electric power losses in distribution systems: Ekpoma, Edo State, Nigeria as a case study. The International Journal of Engineering and Science.

Global Scientific Journal. (2023). Reliability and availability analysis of a gas turbine power plant (8 GTs), south-western Nigeria.

Grigsby, L. L., Harlow, J. H., & McDonald, J. D. (2006). Electric power engineering handbook (2nd ed.). CRC Press.

IJRASET. (2023). Performance assessment of a gas turbine power plant. International Journal for Research in Applied Science and Engineering Technology.

International Bar Association. (2023). Prospects of embedded generation in the Nigeria's power sector.

Jagdeep, E. (2018). Real time study on technical and non-technical losses in distribution system and reduction techniques.

Journal of Mechanical Engineering and Sciences. (2024). Energy, exergy, and exergoeconomic analysis of a gas turbine plant with integrated waste heat recovery.

Journal of Thermal Analysis and Calorimetry. (2024). Exergy analysis of a gas turbine cycle power plant: A case study of power plant in Egypt.

Khonjelwayo, B., & Nthakheni, T. (2021). Determining the causes of electricity losses and the role of management in curbing them: A case study of City of Tshwane Metropolitan Municipality, South Africa. Journal of Energy in Southern Africa.

Komolafe, O. M., & Udofia, K. M. (2020). Review of electrical energy losses in Nigeria. Nigerian Journal of Technology.

Living, O., Nnamchi, S. N., Ukagwu, K. J., Abdulkarim, A., & Jagun, Z. O. (2023). Minimization of electric power losses on 132 kV and 220 kV Uganda electricity transmission lines. Energy and Power Engineering.

Nta, E. E. (2022). Evaluation of electric power losses on 33/11 kV distribution feeder networks in Uyo urban, Nigeria using loss factor approach. European Journal of Electrical Engineering and Computer Science.

Obateru, F. B., Odewumi, O. S., & Agbelusi, E. A. (2019). Diversity and abundance of avian species of Loburo Forest (Redemption Camp), Ogun State, Nigeria. Journal of Research in Forestry, Wildlife and Environment.

Ohunakin, O. S., Adaramola, M. S., & Oyewola, O. M. (2014). Performance evaluation and economic analysis of a gas turbine power plant in Nigeria. Energy Conversion and Management.

Oyedepo, S. O., Fagbenle, R. O., Adefila, S. S., & Adavbiele, S. A. (2015). Assessment of performance indices of selected gas turbine power plants in Nigeria. Energy Science & Engineering, 3(3).

Oyediji, T. (2022, February 15). How RCCG moved to the Redemption Camp. City People.

Pegado, R., Ñaupari, Z., Molina, Y., & Castillo, C. (2019). Radial distribution network reconfiguration for power losses reduction based on improved selective BPSO. Electric Power Systems Research.

Power Sector Reform in Nigeria: Challenges and Solutions. (2018). IOP Conference Series: Materials Science and Engineering, 413, 012037.

RCCG Electrical Generation and Distribution Department. (2021). Internal engineering and metering records, Redemption City of God.

RCCG Electrical Generation and Distribution Department. (2022). Energy consumption records for the 11 kV feeders, January–December 2022 [Data set].

RMI & Lion's Head Global Partners. (2023). Unlocking renewable embedded generation in Nigeria.

RMI. (2023). Renewable embedded generation can shelter Nigeria from electricity shortage [Press release].

RMI. (2025). Increasing affordable electricity supply in Nigeria through embedded generation.

RSC Sustainability. (2025). Unlocking renewable energy materials in Nigeria: Availability, application, and roadmap for sustainability.

ScienceDirect. (2025a). Optimizing the energy and economic performance of a 125 MW gas turbine power plant through exergy analysis.

ScienceDirect. (2025b). The burden of the broken grid: Modelling power-sector reliability to support low carbon development in Nigeria.

Starlett. (2013, September 25). Redemption City: Largest City of God on Earth.

Sultan Qaboos University. (2017). Thermal performance of gas turbine power plant based on exergy analysis. Applied Thermal Engineering.

Tandfonline / Engineering Applications of Computational Fluid Dynamics. (2024). Thermal performance analysis of gas turbine power plant using soft computing techniques: A review.

The Energy for Growth Hub. (2023). How the global energy crisis is improving the prospects of solar in Nigeria.

The Energy for Growth Hub. (2025). 160 days in the dark: Understanding electricity unreliability in Nigeria.

The Redeemed Christian Church of God. (2022). Our history by the Redeemed Christian Church of God.

Theraja, B. L., & Theraja, A. K. (2008). Electrical technology (24th ed., Vol. 5). S. Chand & Company.

Works in Progress Magazine. (2025). Every generator is a policy failure.

Xie, J., Chen, C., & Long, H. (2021). A loss reduction optimization method for distribution network based on combined power loss reduction strategy. Complexity, 2021.

Zawya. (2025, January 8). With technology, Nigeria's dependence on noisy, expensive diesel generators can stop.