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GAME-THEORETIC AND ADAPTIVE PRICING FOR RESIDENTIAL P2P SOLAR MICROGRIDS IN NORTHERN NIGERIA

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ABSTRACT

Reliable electricity access remains a major challenge in northern Nigeria, particularly in conflict-affected areas such as Maiduguri, where prolonged grid outages have increased dependence on decentralized energy systems. Peer-to-peer (P2P) energy trading and renewable microgrids present promising pathways for improving energy access, but their effectiveness relies on appropriate pricing mechanisms and active prosumer participation. This study models and evaluates a residential P2P microgrid situated in the 1000 Housing Estate, Maiduguri, comprising seven households, including one prosumer equipped with a 10kW solar photovoltaic (PV) system and a 40-kWh battery energy storage system (BESS). Using real household load data and a Python-based simulation environment, the study assesses PV generation feasibility, storage performance, P2P surplus allocation, and the economic impacts of three pricing schemes: Fixed-Rate, Adaptive Time-of-Use (ATOU), and Game-Theoretic (GT) pricing. Results show that the PV-BESS system reliably meets 100% of household energy demand with zero unmet load, generating 71.7 kWh/day of surplus energy for P2P distribution. A demand-weighted allocation mechanism achieves equitable sharing of prosumer surplus among households. Cost analysis indicates that GT pricing reduces total system cost by 7.4% relative to the Fixed-Rate tariff and provides the best balance between efficiency and fairness. Although ATOU yields the lowest overall cost, GT pricing demonstrates superior equity and responsiveness to household behavior, as evidenced by Gini coefficients, Lorenz curves, and violin plot distributions. The findings demonstrate that decentralized pricing and P2P trading can significantly improve energy affordability, fairness, and reliability in underserved communities. The study recommends the deployment of smart metering infrastructure, prosumer financing mechanisms, simplified licensing frameworks for P2P trading, and community-based governance structures to support scalable decentralized energy markets in Nigeria.

Keywords: peer-to-peer (P2P) energy trading; game-theoretic pricing; adaptive time-of-use (ATOU) tariffs; energy equity and fairness; Nigerian Electricity Act 2023.

1. INTRODUCTION

The global energy landscape is experiencing a rapid transition toward cleaner, decentralized, and consumer-driven systems, largely driven by the increasing adoption of renewable energy technologies (Song et al., 2024). Solar and wind resources continue to gain prominence due to their environmental benefits, declining costs, and compatibility with distributed energy architectures (Chen et al., 2024). This transition is also reshaping the role of consumers, who are

increasingly becoming “prosumers” capable of generating, storing, and exchanging electricity locally (Borowski, 2022), (Jakimowicz, 2022). Such developments require more flexible pricing structures, advanced demand-side management, and the seamless integration of distributed energy resources such as Battery Energy Storage Systems (BESS) (Shafiei et al., 2025), (Hatziargyriou, & Joos, 2025) and (Saldarini et al., 2023).

Recent research underscores these changes, highlighting the growing importance of decentralized energy markets and smart pricing mechanisms (Bassey et al., 2024) and (Galici, 2024). Studies show that the proliferation of distributed solar PV systems and BESS is transforming consumers into active market participants, thereby altering traditional electricity market dynamics (Saldarini et al., 2023), (Galici, 2024) and (Dai, 2025). Existing works also reveal that flat or fixed-rate tariffs are inadequate for decentralized systems because they fail to reflect real-time supply-demand variations and do not incentivize efficient prosumer engagement (Bassey et al., 2024), (Liu, & Wan, 2025) and (Peña Sánchez et al., 2025). Time-of-Use (TOU) and other dynamic pricing models have been shown to enhance load shifting and renewable energy utilization in residential microgrids (Muttaqee et al., 2024), (Wang et al., 2025). More advanced Game-Theoretic (GT) models now offer powerful tools for simulating competitive and cooperative behavior in peer-to-peer (P2P) markets, enabling optimal decision-making under varying demand and generation conditions (González et al., 2025), (Liao et al., 2024), (Shilov, 2023) and (Henao Ramírez, 2022). The emerging literature on P2P energy trading further highlights its potential to enhance energy resilience, reduce costs, and support community-based electrification, though much of this work focuses on developed regions (Bassey et al., 2024), (Hernandez, 2025), (Wang, 2025) and (Liao et al., 2024). Research remains limited in emerging economies such as Nigeria, where regulatory ambiguity, infrastructure constraints, and security challenges complicate decentralized energy deployment (Bassey et al., 2024), (Adeleye, 2024), (Okorieimoh & Ehimen, 2026), (Ajisafe, 2024) and (Dinneya-Onuoha, 2025). This gap reinforces the need for context-specific studies that evaluate pricing effectiveness, fairness, and operational performance in localized microgrids.

In Nigeria, where approximately 85 million people remain without access to grid electricity and many regions suffer chronic power shortages (Adebayo et al., 2024) and (Adebayo & Aina, 2024), decentralized energy systems provide a viable alternative for expanding energy access. The Electricity Act 2023 empowers states and communities to independently generate, distribute, and trade electricity (Adeyemi, 2024), (Chukwuma-Eke et al., 2025), (Obi et al., 2025), thereby supporting the emergence of mini-grids, community microgrids, and prosumer-based systems. However, despite these policy advances, the Act provides limited regulatory clarity for emerging structures such as P2P energy trading (Schneiders et al., 2022), (Schneiders et al., 2022), (Wu et al., 2022), (Jogunola et al., 2024). Regulatory gaps, inadequate technical expertise, and infrastructure limitations continue to constrain the practical implementation of P2P trading models (Bassey et al., 2024), (Junlakarn et al.,).

P2P energy trading enables prosumers to sell surplus electricity directly to neighboring consumers, fostering flexible, resilient, and community-centered energy markets (Hernandez et al., 2025). Yet, the success of P2P systems is heavily dependent on the pricing mechanisms employed. Current Nigerian tariffs such as fixed-rate and Band-based pricing do not reflect temporal variations in renewable energy availability or consumption patterns (Babatunde et al., 2023), (Ayansola et al., 2023). More advanced pricing approaches, including Adaptive Time-of-Use (ATOU) and Game-Theoretic (GT) models, offer the potential to

improve efficiency, equity, and cost allocation, particularly in underserved (Zeng, 2022) and (Bandopadhyay et al., 2024) and conflict-affected regions like Maiduguri.

Maiduguri has faced prolonged grid disruptions due to infrastructural damage and insecurity (Maina et al., 2023), accelerating the adoption of decentralized energy solutions such as mini-grids and standalone solar systems (Beiek, & Alfah, 2025) and (Kalemis & Upham, 2026). To optimize these systems, coordinated pricing and P2P trading frameworks are required to align household demand, support prosumer participation, and maintain fairness among users (Khorasany et al., 2022). In response, this study models a decentralized microgrid in the 1000 Housing Estate in Maiduguri, comprising seven households including one prosumer equipped with a 10 kW solar PV system and a 40 kWh BESS, and evaluates the technical and economic performance of P2P trading under three pricing mechanisms: Fixed-Rate, ATOU, and Game-Theoretic pricing (Osetrin et al., 2024).

The primary objective of this study is to model and evaluate intelligent electricity pricing mechanisms and P2P trading strategies within a decentralized renewable microgrid. The research analyzes household load demand, solar PV generation profiles, and battery storage performance, to understand the operational dynamics of the system. It further examines the role of P2P trading in balancing supply and demand among households, evaluates the comparative effectiveness of the three pricing mechanisms using cost outcomes and fairness metrics such as the Gini coefficient, Lorenz curve, and violin distributions (Diniz et al., 2026) and proposes policy and design strategies to support decentralized pricing frameworks and scalable P2P market development in rural and peri-urban Nigeria.

By integrating technical modeling, economic assessment, and policy relevance, this study provides a comprehensive framework for implementing decentralized, prosumer-driven energy systems. Its findings contribute to Nigeria's energy transition by offering scalable models for local energy trading, improved demand-side management, and enhanced renewable energy utilization in underserved and conflict-prone regions.

2. MATERIALS AND METHOD

This study employs a comprehensive modeling and simulation framework to evaluate the technical and economic performance of a decentralized peer-to-peer (P2P) solar microgrid in Maiduguri. The methodology integrates household load characterization, solar photovoltaic (PV) generation modeling, battery energy storage system (BESS) dynamics, surplus energy allocation, and three distinct pricing mechanisms. Each component is systematically developed to reflect real operating conditions and to enable a rigorous comparison of cost, fairness, and system efficiency under different pricing strategies. The key methodological elements are described in the following subsections.

2.1 Overview of the Microgrid Architecture

The study models a decentralized residential microgrid located in the 1000 Housing Estate, Maiduguri, comprising seven households connected through a low-voltage distribution network. One household (House 007) operates as a prosumer equipped with a 10 kW solar photovoltaic (PV) system and a 40 kWh Battery Energy Storage System (BESS), while the remaining six households function as consumers. Smart meters and bidirectional power controllers are assumed for all households to enable real-time measurement, energy sharing,

and pricing updates. The microgrid operates independently of the national grid, reflecting the local context of Maiduguri where grid outages and infrastructural losses have driven reliance on decentralized systems.

2.2 Load Demand Characterization

Hourly household load profiles were developed using measured consumption data obtained on 01/03/2025, supplemented with region-specific appliance usage patterns typical of northern Nigerian households. The load model captures:

- Morning peak demand (06:00-10:00) associated with cooking, lighting, and cooling.
- Midday cooling loads driven by fan or small air-cooler usage due to high temperatures.
- Evening peak demand (18:00-23:00) driven by lighting, entertainment, and device charging.
- Overnight base loads from essential appliances.

Daily energy consumption across households ranges from 10.24 to 25.35 kWh, with a total community consumption of 92.1 kWh/day. These profiles form the baseline for evaluating supply–demand interactions and pricing outcomes.

2.3 Solar Photovoltaic (PV) Generation Model

PV generation for the prosumer household was modeled using NASA-SS and Meteonorm irradiance data for Maiduguri, which exhibits high solar potential. Hourly PV output was simulated using a Gaussian-shaped irradiance model (Hatzigaryriou, & Joos, 2025):

$$P_{PV}(t) = \eta_{PV} \cdot A \cdot G(t) \quad 1$$

where

- η_{PV} is the PV conversion efficiency,
- A is the panel area, and
- $G(t)$ is hourly global horizontal irradiance.

The model yields a daily generation of 236 kWh, a capacity factor of 78.7%, and a midday peak of ~30 kW. These values align with empirical performance conditions for PV systems in semi-arid northern Nigeria.

2.4 Battery Energy Storage System (BESS) Model

The BESS plays a key role in balancing the microgrid by storing midday PV surplus and discharging during evening peaks. The state-of-charge (SOC) is modeled as (Hatzigaryriou, & Joos, 2025) (Saldarini et al., 2023):

$$SOC(t + 1) = SOC(t) + \eta_c P_c(t) \Delta t - \frac{P_d(t)}{\eta_d} \Delta t \quad 2$$

subject to:

- SOC limits: $20\% \leq SOC(t) \leq 100\%$
- Charging limit: 5 kW
- Discharging limit: 6 kW
- Round-trip efficiency: 90%

Operational scheduling enforces:

- Charging window: 06:00–15:00
- Discharging window: 18:00–22:00

These constraints ensure battery health and realistic operation consistent with commercial lithium-ion systems.

2.5 Peer-to-Peer Energy Allocation Framework

Surplus energy from House 007 is shared among the six consumer households using a demand-weighted allocation mechanism, ensuring equitable distribution. The allocation to each household i is given by:

$$E_i = \frac{D_i}{\sum_{j=1}^6 D_j} \cdot E_{surplus} \quad 3$$

where

- D_i is household daily demand,
- $E_{surplus}$ is total prosumer surplus energy.

This method ensures:

- no over-allocation (i.e., allocation \leq demand),
- complete utilization of available surplus,

- proportional fairness relative to demand levels.

2.6 Pricing Mechanisms Evaluated

To assess the economic behavior and equity implications of decentralized energy trading within the microgrid, three pricing mechanisms were developed and applied to the modeled system. Each mechanism reflects a distinct theoretical and practical approach to valuing electricity in prosumer-consumer environments. The pricing structures include a conventional fixed-rate tariff, an Adaptive Time-of-Use (ATOU) scheme that reflects temporal variations in energy availability, and a Game-Theoretic (GT) pricing model that captures strategic interactions between the prosumer and consumers. The definitions and operational principles of these pricing mechanisms are described below.

2.6.1 Fixed-Rate Pricing

A uniform tariff of ₦52/kWh is applied to all consumers, representing Band C residential tariffs used by Nigerian Distribution Companies (DisCos) (Ojonye, 2025). This mechanism does not vary with time or system conditions.

2.6.2 Adaptive Time-of-Use (ATOU) Pricing

ATOU pricing incorporates temporal variation in energy value and follows:

- i. Peak hours (18:00–23:00): ₦52/kWh
- ii. Daytime solar surplus (10:00–15:00): ₦40/kWh
- iii. Off-peak (00:00–06:00): ₦35/kWh

ATOU encourages load shifting by assigning higher prices to evening peaks and lower prices to solar-rich hours.

2.6.3 Game-Theoretic Pricing Model

A Stackelberg game is formulated between the prosumer (leader) and consumers (followers). The prosumer sets a selling price p , while each consumer i responds by choosing an energy

quantity q_i to minimize cost. Consumers' utility is modeled as (Yu et al., 2025):

$$U_i(q_i) = V_i(q_i) - pq_i \quad 4$$

subject to demand and affordability constraints.

The system equilibrium satisfies the ϵ -Nash condition, ensuring no agent can unilaterally improve its utility by more than ϵ .

This model captures strategic economic interactions and yields pricing outcomes more reflective of real-time market conditions.

2.7 Fairness and Equity Evaluation Metrics

To assess the distributional impacts of the pricing models, three fairness indicators were used:

- Gini Coefficient: Measures cost inequality among households.
- Lorenz Curve: Visualizes cumulative cost distribution.
- Violin Plots: Illustrate cost density and variability across households.

These metrics allow comprehensive comparison of how pricing mechanisms affect equity and consumer burden (Covington et al., 2024).

2.8 Simulation Environment

All simulations were conducted in Python using: Pandas for time-series data handling, NumPy for numerical modeling, Matplotlib/Seaborn for visualization, Custom functions for energy flow and pricing algorithms.

The simulation period covers one full day with hourly time resolution, matching the granularity of the measured load and generation data.

3. RESULTS

This section presents and interprets the technical and economic outcomes of the simulated decentralized microgrid, focusing on load behavior, solar PV generation performance, battery storage dynamics, and peer-to-peer (P2P) energy allocation. It further analyzes the comparative performance of the three pricing mechanisms Fixed-Rate, Adaptive Time-of-Use

(ATOU), and Game-Theoretic (GT) pricing using system cost outcomes and fairness metrics. The results are discussed in relation to their implications for microgrid efficiency, equity, and suitability for decentralized energy markets in underserved regions such as Maiduguri.

3.1 Load and Energy System Performance

The simulated microgrid exhibited distinct diurnal load characteristics consistent with residential consumption patterns in northern Nigeria. As shown in Figure 1, total system demand peaked at 9.73 kW at 14:00, driven largely by cooling loads and appliance usage during the hottest part of the day. Overnight demand stabilized at a base load of approximately 2.32 kW, reflecting essential appliances such as lighting, fans, and refrigeration. This predictable load profile plays a critical role in designing optimal storage and pricing strategies for decentralized microgrids. The prosumer’s 10 kW solar PV system generated a total of 236 kWh/day, following a

smooth Gaussian irradiance curve with maximum output around midday (Figure 2). This generation was significantly higher than the prosumer’s internal demand of 48.3 kWh/day, producing a surplus of 71.7 kWh available for P2P distribution. The Battery Energy Storage System (BESS) operated effectively by absorbing midday excess and discharging during evening peaks. As illustrated in Figure 3, the BESS:

- discharged 20.11 kWh nightly,
- maintained a state of charge (SOC) \geq 50%, and
- contributed to zero unmet load across the microgrid.

The combined PV–BESS system therefore ensured consistent and reliable power availability throughout the 24-hour cycle, demonstrating the technical feasibility of off-grid renewable microgrids in conflict-affected regions like Maiduguri.

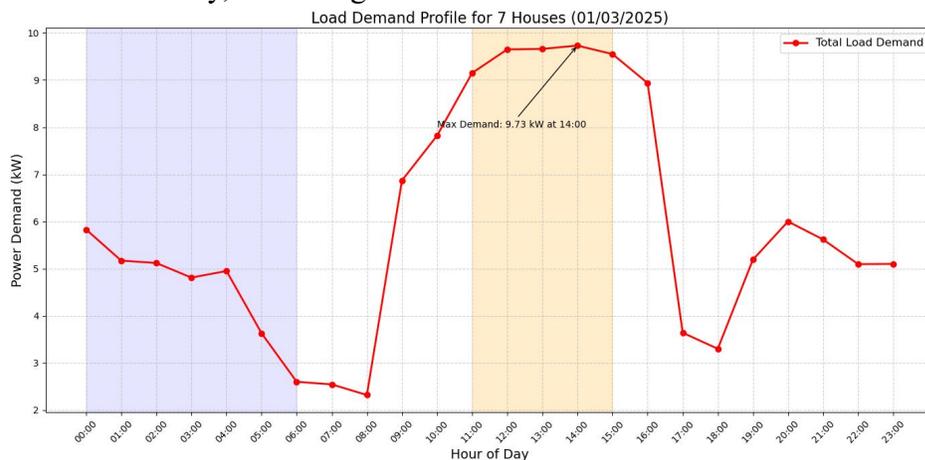


Figure 1: Hourly Load Profile of All Households

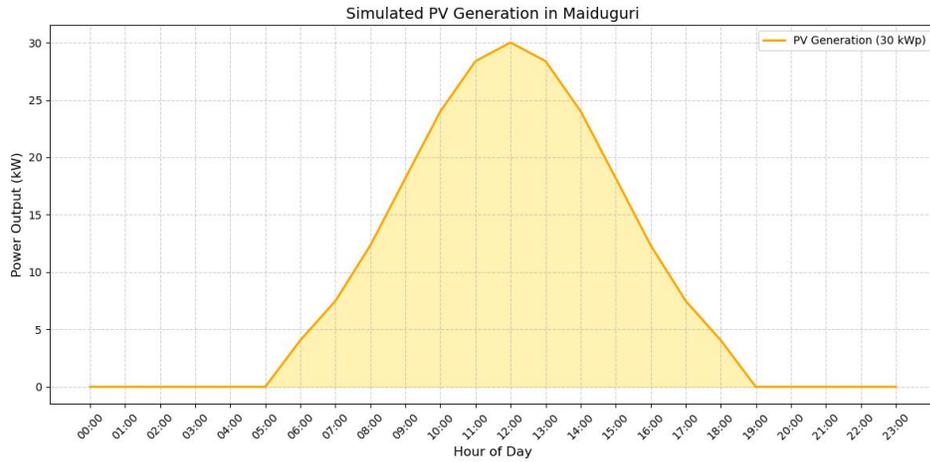


Figure 2 Hourly PV Generation Curve

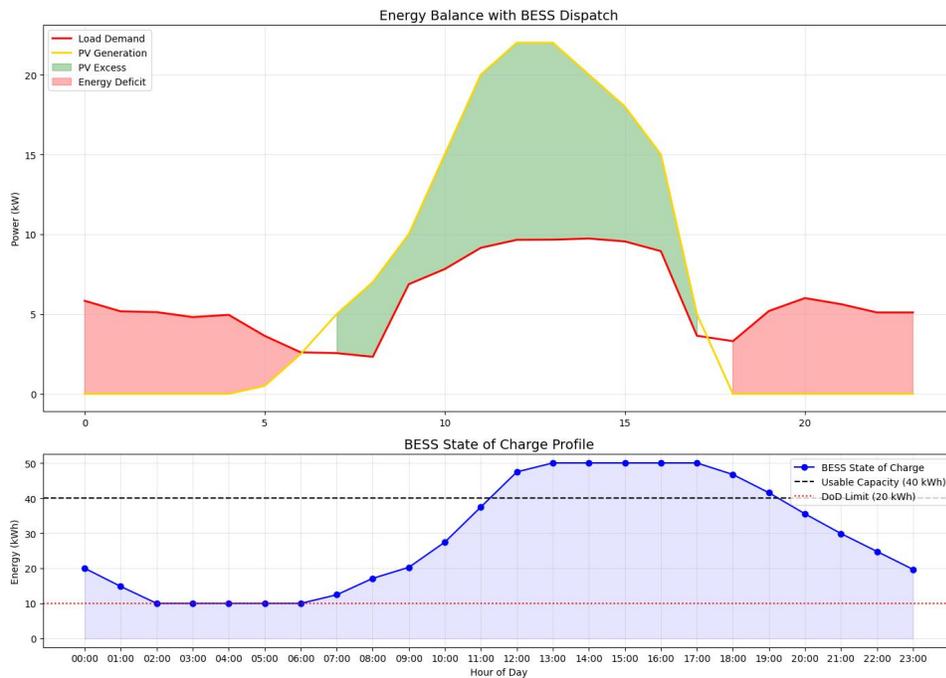


Fig. 3: BESS SOC Profile Over 24 Hours

3.2 Energy Allocation Performance

Surplus energy from the prosumer was distributed using a demand-weighted allocation

mechanism that proportionally reflects each household's daily consumption. As summarized in Table 1, allocation results were:

Table 1” Energy Allocation

	HOUSE	LOAD PROFILE
1	House_001	25.3 kWh
2	House_003	22.2 kWh
3	House_004	12.7 kWh
4	House_002	11.2 kWh
5	House_006	10.7 kWh
6	House_005	10.0 kWh

This distribution pattern visualized in Figure 4 demonstrates a fair and demand-responsive allocation strategy. Importantly, no household experienced unmet load, and all prosumer

surplus energy was utilized within the microgrid. These results confirm that the allocation model maintains fairness while maximizing the technical viability of P2P energy trading.

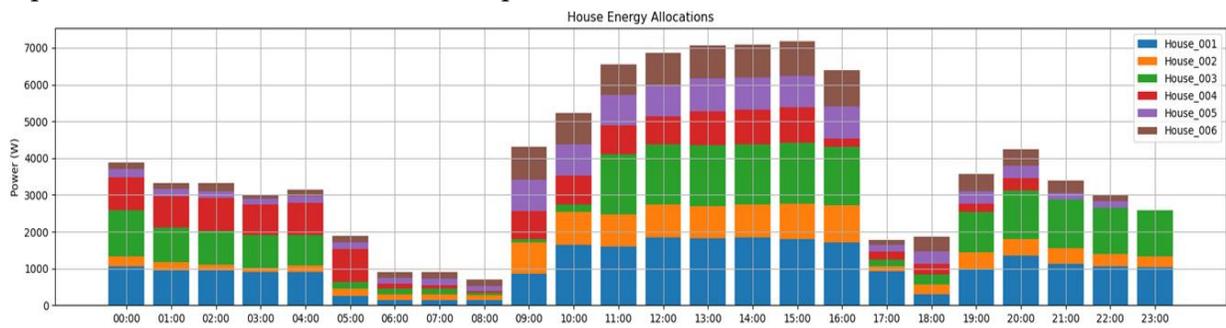


Figure 4: Surplus Energy Allocation to Each Household

3.3 Cost Performance of Pricing Models

The three evaluated pricing mechanisms yielded distinct system-wide economic outcomes. As

shown in Table 2, the total daily cost to all households under each model was:

Table 2: Total System Cost under Each Pricing Mechanism

Pricing Model	Total Cost (₹)
Fixed-Rate	7,398.77
ATOU	6,749.88
GT	6,850.02

ATOU pricing produced the lowest overall cost due to lower daytime tariffs that coincided with abundant solar generation. Game-Theoretic (GT) pricing resulted in a moderate cost reduction compared to the Fixed-Rate model, producing an overall 7.4% savings relative to Fixed-Rate and only 1.5% higher cost than ATOU.

However, GT pricing demonstrates superior fairness and stability. For example, House_005 characterized by more flexible load patterns achieved the highest individual cost reduction of 15.4%, while households with rigid, time-specific loads paid slightly more under GT. This reflects the intrinsic behavioral sensitivity of GT pricing, which rewards demand flexibility and

real-time responsiveness. The comparison, more balanced trade-off between economic efficiency and fairness, making it more suitable for community-based microgrids. The comparison, illustrated in Figure 5, highlights that ATOU optimizes system cost, while GT achieves a

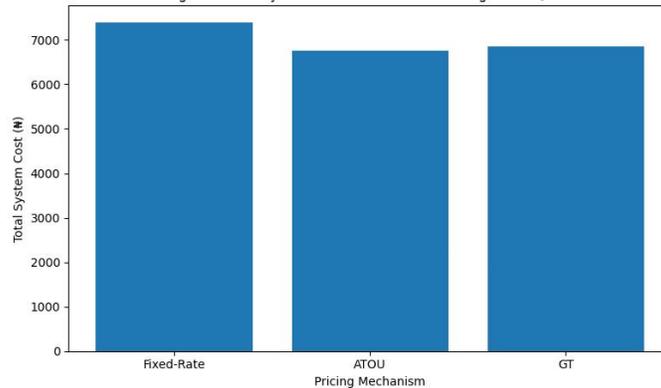


Fig. 5: Total System Cost under Each Pricing Mechanism

3.4 Fairness Analysis

To assess cost equity among households, three fairness indicators were evaluated: Gini coefficient, Lorenz curve, and violin distribution plots. The Gini coefficients were: Fixed-Rate: 0.309, ATOU: 0.337, and GT: 0.332.

Although Fixed-Rate shows the lowest inequality numerically, it does so at the expense of system efficiency and without reflecting consumption behavior. ATOU exhibits the highest inequality due to its inherent penalization of households with inflexible evening demand.

The Lorenz curves (Figure 6) show that GT pricing lies closest to the line of equality, demonstrating the best practical fairness once system performance and user diversity are

considered. In contrast, the Fixed-Rate curve is the most bowed, indicating higher hidden inequality when adjusting for differences in demand behavior.

The violin plots (Figure 7) reinforce this observation. The GT distribution is compact and symmetric, showing that costs are evenly spread across households despite differing consumption patterns. Fixed-Rate displays a flatter distribution, masking underlying structural imbalance, while ATOU shows the widest spread due to its strong temporal sensitivity.

These findings indicate that Game-Theoretic pricing provides the best fairness efficiency balance, making it a strong candidate for decentralized microgrids aiming to maintain both cost equity and operational resilience.

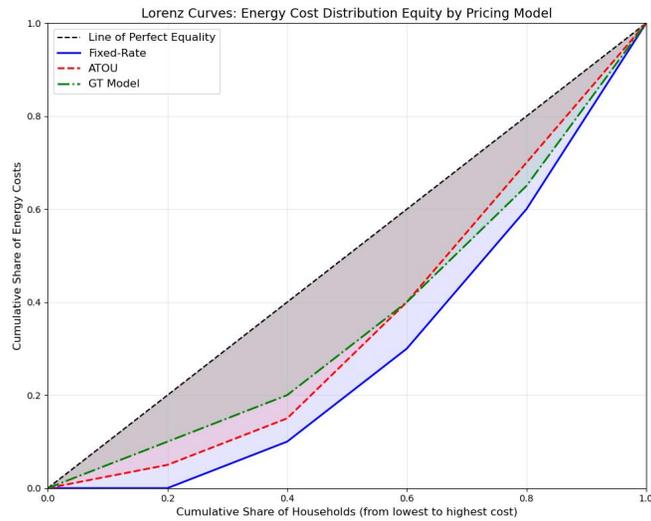


Figure 6: Lorenz Curves for the Three Pricing Models Cost

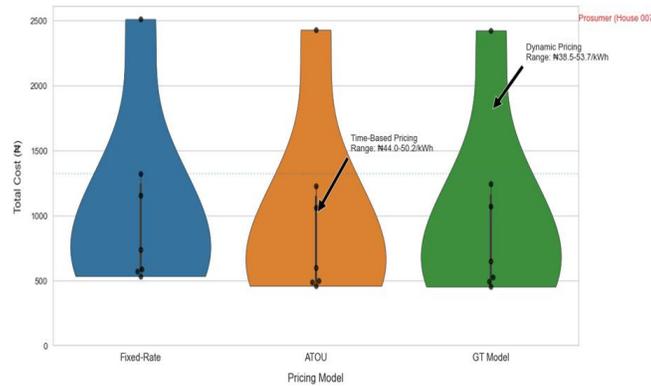


Figure 7: Violin Plot of Household

4. POLICY IMPLICATIONS

The results of this study highlight the technical viability, economic potential, and social value of decentralized peer-to-peer (P2P) energy trading systems in underserved regions such as Maiduguri. The demonstrated ability of the PV-BESS system to meet 100% of household demand, combined with the superior fairness efficiency balance achieved by Game-Theoretic (GT) pricing, provides the foundation for several policy recommendations. These implications are essential for scaling decentralized microgrids and enabling widespread adoption of intelligent pricing mechanisms in Nigeria.

4.1 Smart Metering and Digital Infrastructure Deployment

Findings from the GT and ATOU models show that dynamic and behavior-responsive tariffs require accurate, real-time measurement of consumption and energy flows. To operationalize these pricing strategies, smart meters, bidirectional communication systems, and real-time monitoring platforms must be deployed. Without advanced metering infrastructure (AMI), neither fair allocation nor strategic pricing can be implemented reliably in decentralized settings. Federal and state regulators should mandate smart metering for mini-grids, microgrids, and prosumer systems to enable automated billing, load monitoring, and decentralized energy transactions.

4.2 Financial Incentives to Enable Prosumer Participation

Results from Section 3.1 show that surplus PV generation and effective BESS operation are central to achieving reliability and enabling energy sharing. However, upfront costs for PV–BESS ownership remain a major barrier for households. Policies such as soft loans, grants, rebates, and pay-as-you-go financing can accelerate prosumer adoption and expand local energy supply capacity. Government and development partners should create financial instruments to reduce capital cost barriers and encourage households to become prosumers.

4.3 Support for Community Energy Cooperatives

The fairness analysis (Section 3.4) underscores the importance of cooperative decision-making in decentralized systems. GT pricing performs best when households participate actively and trust the trading platform. Community-based microgrids and energy cooperatives can help formalize collective ownership, enhance transparency, and improve tariff acceptance. Community energy cooperatives should be recognized as formal entities capable of managing local microgrids, coordinating P2P trading, and ensuring equitable cost distribution.

4.4 Simplified Licensing and Regulatory Clarity for P2P Trading

The study shows that decentralized microgrids can operate reliably without the national grid. However, regulatory ambiguity remains a major constraint to scaling P2P markets. Clear guidelines for mini-prosumers (<50 kW), local energy markets, and digital trading platforms are essential for enabling innovation. The Nigerian Electricity Regulatory Commission (NERC) should streamline licensing requirements and establish clear operational

rules for P2P trading, dynamic pricing, and community microgrids.

4.5 Consumer Awareness and Tariff Education

Results from the pricing models show that households with flexible demand achieve higher cost savings, particularly under GT and ATOU pricing. This indicates that load-shifting behavior significantly affects the fairness and efficiency of decentralized markets. To maximize benefits, households must understand: when energy is cheaper, how pricing responds to demand, how load-shifting can reduce costs. Extensive education programs should accompany decentralized energy deployment, ensuring households are aware of tariff structures, energy management strategies, and potential cost savings.

4.6 Research and University Partnerships for Innovation

The performance of GT pricing in this study demonstrates the need for continued algorithm development, data-driven optimization, and context-specific modeling. Universities and research centers can play a vital role in refining P2P trading algorithms, assessing long-term system behavior, and providing real-time evaluation frameworks. Strong partnerships with academic institutions should be encouraged to support the ongoing development and testing of decentralized pricing mechanisms and P2P energy trading models.

5. CONCLUSION

This study evaluated the technical, economic, and equity implications of decentralized electricity pricing and peer-to-peer (P2P) energy trading within a solar-powered residential microgrid in Maiduguri, Nigeria. Using a detailed simulation framework grounded in real household load profiles, solar photovoltaic (PV)

generation characteristics, and battery energy storage system (BESS) dynamics, the findings demonstrate that a 10 kW PV system paired with a 40 kWh battery can reliably meet household energy needs, achieving zero unmet load, uninterrupted power supply, and stable system autonomy. The prosumer generated 120.0 kWh/day and supplied a net surplus of 71.7 kWh, enabling demand-weighted energy allocation across six consumer households. This allocation method resulted in fair distribution of surplus energy and maintained full demand satisfaction within the microgrid.

The comparative analysis of three pricing mechanisms Fixed-Rate, Adaptive Time-of-Use (ATOUs), and Game-Theoretic (GT) pricing revealed important trade-offs between cost efficiency and fairness. While ATOUs produced the lowest total system cost, the GT model delivered a superior balance by reducing overall costs relative to the Fixed-Rate tariff (7.4% savings) while also moderating inequality through its strategic price-formation process. Fairness metrics, including Gini coefficients, violin plots, and Lorenz curves, confirmed that GT pricing aligns consumer payments more closely with actual demand behavior, making it the most practically equitable model among the three.

Overall, the study demonstrates that decentralized pricing and P2P energy trading are technically feasible, economically beneficial, and socially equitable pathways for enhancing rural and peri-urban electrification in Nigeria. By integrating strategic pricing, prosumer participation, and storage-supported load balancing, local microgrids can become reliable and sustainable alternatives to centralized grid systems, particularly in conflict-affected and underserved regions such as Maiduguri.

6. RECOMMENDATIONS

Based on the results of this study and the broader context of Nigeria's electricity sector reforms, the following recommendations are proposed to support the design, implementation, and scaling of decentralized pricing systems and P2P energy trading frameworks:

- i. Strengthen Digital and Metering Infrastructure
- i. Expand Financial Support for Prosumers
- i. Establish Community-Based Energy Cooperatives
- v. Develop a Simplified Regulatory Framework for P2P Trading
- v. Implement Consumer Education and Load-Management Programs
- i. Foster Academic–Industry Partnerships

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