

Economic and Regulatory Perspectives on Deregulated Electricity Markets: A Case Study in Brazil with Insights for Honduras

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Abstract— The liberalization of electricity markets has created opportunities for consumers to reduce costs and access more sustainable energy sources, while also raising new regulatory and operational challenges. This paper proposes a replicable decision-support framework for the migration of qualified consumers to deregulated electricity markets, comprising automated billing data extraction, financial scenario simulation, and sensitivity analysis under tariff variability. The framework is applied to a case study at the Federal University of Pará (UFPA), Brazil, where two contractual modalities were evaluated based on real proposals from energy traders. Model results were validated against historical invoice data, with relative errors below 2%. Results show potential savings between 22.2% and 28.2% compared to the regulated market over a five-year horizon, with savings preserved across all tariff scenarios analyzed, including a conservative case yielding R\$ 13.9 million in total savings. A purpose-built energy management platform supporting PDF invoice parsing, multi-unit data aggregation, and market simulation is also presented and compared with existing tools. Additionally, the paper provides a comparative regulatory analysis of the Honduran electricity market, discussing how the Brazilian findings can inform the expansion of qualified consumer participation in the Honduran wholesale market. The findings highlight both the opportunities for efficiency and competitiveness and the regulatory barriers that must be addressed for an effective transition in developing economies.

Keywords—*Deregulated electricity market, energy tariff simulation, energy management platform, qualified consumers, regulatory challenges*

I. INTRODUCTION

A. General Considerations

In recent years, the number of countries that have opened the electricity market, at least for high industrial consumers, has increased considerably. The opening of the market means that users are free to choose their energy supplier from a new stakeholder, called retailers; in this scenario, there is an obligation to provide access to transmission and distribution networks to third parties under a previously agreed cost of use and physical limitations. According to the market structure, international experiences show that the market opening translates into lower prices. One of the first studies of deregulated markets is presented in [1], which reviews the experience of countries that have opened markets and considers

the key elements of market reform. The authors conclude that deregulated markets open the way to greater competition in generating, supplying, and consuming electricity, which maximizes and improves consumer choice and purchasing conditions.

B. Literature Review

Studies on deregulated electricity markets have expanded significantly since the early 1990s, addressing both economic and technical dimensions. Figures 1 and 2 illustrate the co-occurrence of keywords in literature. Figure 1 shows a strongly connected cluster of terms such as deregulation, electric power systems, and commerce, reflecting the close interaction between market liberalization, economic models, and system operation. The temporal color gradient highlights the evolution of research focus: from early analyses of economic impacts and industrial economics (2006–2010) toward more technical challenges such as optimization, power markets, and stability in systems with high renewable penetration (2012–2014).

Figure 2 further organizes this knowledge into thematic clusters. The red cluster relates to technical foundations, including planning, reliability, and transmission. The yellow cluster emphasizes optimization aspects such as congestion management and voltage control. The blue cluster addresses system stability issues, highlighting frequency control, stochastic systems, and the variability introduced by renewable generation. Finally, the green and purple clusters represent the economic and commercial dimensions of deregulated markets, focusing on market design, investment, and profitability in liberalized environments. Overall, this transition reflects a broader shift in research agendas: from macroeconomic studies of liberalization toward detailed analyses of technical and operational aspects, particularly in contexts of high uncertainty and increasing renewable integration.

From the demand-side perspective, large consumers are not passive beneficiaries of liberalization; instead, they must develop explicit market participation and procurement strategies. Previous research shows that liberalized markets may provide incentives for cost reduction and demand-side flexibility, but these benefits depend on market design, financial security, ease of adoption, risk exposure, and the ability of consumers to participate effectively in market mechanisms [2].

The literature presents different approaches to electricity market design and operation, including resource adequacy mechanisms, price exposure, and uncertainty modeling [3], [4]. The main components include generators, power marketers, power exchanges, transmission owners, independent system operators, ancillary service providers, scheduling coordinators, retail service providers, and distribution service providers. In [3], the author takes an interesting approach to market opening. On the one hand, on the consumer side, due to the high volatility of hourly prices depending on the availability of sources, the Market Load Hedge (MLH) is proposed, with the aim of improving price stability and ensuring the necessary income for generators. The importance of the capacity market is also considered, as it ensures the necessary capacity to meet demand in critical hours when other sources are unavailable.

Beyond the bibliometric evolution observed in the keyword maps, the literature on electricity market liberalization emphasizes that market opening should not be interpreted merely as the replacement of regulated tariffs by competitive energy procurement. Rather, successful liberalization depends on the coordinated design of wholesale competition, retail access, transmission and distribution network regulation, market monitoring, and institutional credibility [5], [6]. Classical assessments of electricity market reform show that competition can improve efficiency and consumer choice, but that its performance is highly dependent on market structure, regulatory oversight, and the ability to preserve reliability and long-term investment signals [5], [6]. In this sense, liberalization processes often require adaptive regulatory mechanisms rather than a complete withdrawal of regulation [5]

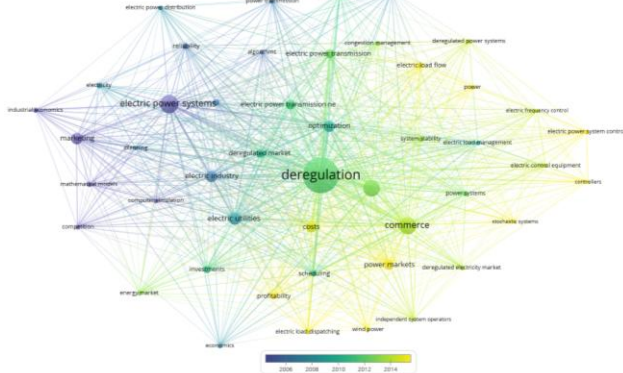


Fig. 1. Overlay keyword co-occurrence map associated with deregulated electricity markets.

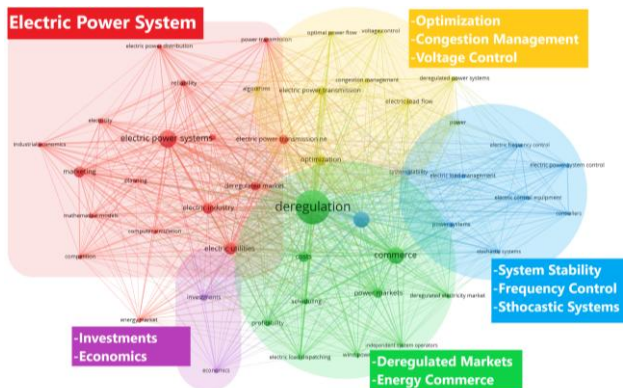


Fig. 2. Thematic keyword map associated with deregulated markets

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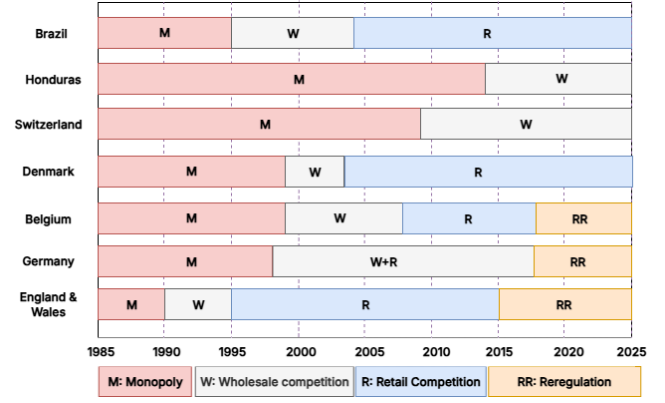


Fig. 3. Evolution of Electricity Market Structures by Country

The market opening brings new challenges in pricing due to the marginal cost of each type of source; in this scenario, different articles have addressed this issue from computational intelligence techniques [4], [7]. The study in [8] evaluates deregulated markets from a price regulation perspective. The authors note that research on this topic has mainly focused on day-ahead markets based on the standard market design structure. The main challenges associated with price forecasting revolve around high volatility, complex interactions between load and generation, variability in market structure, and model complexity when uncontrollable sources are included [8], [9]. The authors emphasize using neural networks over other methods due to their high accuracy.

In this context, the literature on electricity procurement for large consumers provides an important methodological foundation for migration studies. Previous works have modeled procurement decisions through bilateral contracts, pool purchases, self-generation, stochastic optimization, information-gap decision theory, and PPA-based strategies, demonstrating that the optimal contracting structure depends on the interaction between expected prices, uncertainty, risk tolerance, demand patterns, and regulatory constraints [10], [11], [12]. For hydro-dominated systems such as Brazil, these issues are particularly relevant because spot prices and contract values are influenced by hydrological uncertainty, system operation, and regulatory adjustments [11]. Therefore, studies evaluating migration to the free contracting environment should combine deterministic financial comparison with sensitivity or uncertainty analysis, as adopted in this paper.

This study also presents a management platform developed to visualize information extracted from electricity bills. For consumers with multiple consumer units, this type of tool is useful for consolidating information and supporting decision-making. The study in [13] presents a real-time management platform based on meters installed in buildings for energy management in an institution. The software can support energy efficiency and power quality studies by generating graphs, bar charts, and invoice-based reports from meters geolocated in a university's buildings. With the help of this platform, case studies of actions associated with Sustainable Development Goals have been presented in [14], [15], [16], [17], [18], [19], [20].

The development of tools that enhance data visualization is becoming more relevant with advances in database processing.

The use of digital tools for energy management has become increasingly relevant as consumers move from passive tariff payment toward active decision-making. Previous reviews have emphasized the role of energy management systems and aggregators in enabling demand-side participation, flexibility, and improved system performance [21]. In parallel, recent work on electricity invoice datasets has shown the importance of structured billing information and labeled PDF documents for developing automated extraction methods and data-driven electricity market analysis [22]. These contributions support the relevance of the proposed platform, which differs from conventional monitoring tools by integrating invoice parsing, multi-unit aggregation, and pre-migration market simulation.

Figure 3 presents a comparative timeline of electricity market evolution across several countries between 1990 and 2021, highlighting four main stages of liberalization: monopoly, wholesale competition, retail competition, and reregulation.

Initially, most systems operated under a monopoly structure, with vertically integrated utilities controlling generation, transmission, and distribution under regulated tariffs. The first transition typically involved wholesale competition, allowing multiple generators to sell electricity to distributors and large consumers while residential users remained regulated. In countries like Brazil, this step marked an important milestone toward efficiency and modernization of the sector. A more advanced phase introduced retail competition, enabling all consumers, including residential ones, to freely choose their suppliers and stimulating competition based on price and service. However, this openness also brought new challenges, such as price volatility and inadequate investment signals for system reliability. Consequently, several nations adopted partial reregulation mechanisms, introducing capacity markets or regulatory interventions to balance competition with supply security. For Honduras, whose current structure still resembles the monopoly stage, understanding this evolutionary trajectory is crucial. Moving toward wholesale competition, as Brazil has done, could open opportunities for efficiency and investment, but it will require adaptive regulation capable of addressing the same challenges that led other countries to combine liberalization with new regulatory mechanisms.

Despite these advances, important gaps remain. Most studies on free-market migration and electricity procurement focus on industrial or commercial consumers, while public institutions such as universities remain underexplored despite their multi-unit consumption profiles and budgetary constraints [2], [10], [11], [12], [23]. In addition, although procurement risk has been addressed through stochastic, optimization-based, and PPA-oriented models, fewer studies combine real trader proposals, validated billing data, and sensitivity analysis in a practical institutional decision-support framework [10], [11], [12].

Finally, while energy management platforms have been widely discussed, the integration of PDF-based invoice extraction, multi-unit aggregation, financial simulation, and deregulated market comparison within a single pre-migration tool remains limited [21], [22]. This study addresses these gaps

through a Brazilian university case study, an automated billing-data platform, financial scenario analysis, and a comparative regulatory discussion for Honduras.

C. Motivation and Contributions

The recent expansion of deregulated electricity markets in Latin America, particularly in Brazil, has increased the relevance of studies evaluating the technical, economic, and regulatory impacts of consumer migration to the free contracting environment. The Brazilian case is especially relevant because its electricity market combines a regulated contracting environment (ACR) with a free contracting environment (ACL), creating a dual structure in which eligible consumers may compare regulated tariffs with freely negotiated contracts [23], [24].

This transition became even more relevant after Ordinance 50/2022, which expanded the eligibility of Group A consumers to purchase electricity from authorized suppliers in the National Interconnected System from January 2024 onward [25]. In this context, the motivation of this work is twofold: first, to demonstrate the potential economic advantages for qualified consumers, especially large public institutions, when accessing competitive energy markets; and second, to provide insights that can guide other countries in the region, such as Honduras, where liberalization remains limited by regulatory and infrastructural constraints. The main contributions of this study are:

- A replicable decision-support framework for qualified consumer migration to deregulated electricity markets, comprising four structured stages: (i) automated data collection and processing from billing documents; (ii) financial simulation of regulated versus deregulated cost scenarios; (iii) sensitivity analysis under tariff and regulatory variability; and (iv) regulatory feasibility assessment for the target market context. This framework is designed to be transferable to other institutions and jurisdictions facing similar market transition decisions.
- Development of an automated energy management platform capable of extracting, processing, and visualizing consumption and billing data from PDF invoices, supporting strategic decision-making.
- Evaluation of two contractual migration scenarios in Brazil, based on real proposals, quantifying potential savings and highlighting the advantages of renewable energy procurement.
- Comparative analysis between regulated and deregulated markets, identifying benefits such as cost reduction, predictability, and sustainability, while addressing risks linked to tariff volatility and regulatory uncertainty.
- Contextual discussion for Honduras, providing a critical assessment of the legal framework, challenges, and opportunities for increasing qualified consumer participation in the wholesale electricity market.

II. METHODOLOGY

A Brazilian case study was considered to simulate the migration of a qualified consumer to the deregulated electricity market. The simulation was carried out using information obtained from sales agents in Brazil. The proposals received were divided into two modalities.

Case Study Selection. The Federal University of Pará (UFPA) was selected as the case study for several reasons. First, as a large public institution, UFPA meets the minimum demand threshold required to qualify as a free market consumer under Brazilian regulations. Second, the availability of a complete historical series of electricity invoices — spanning multiple consumer units across the campus — enabled a robust and representative simulation. Third, the institution has an ongoing energy management program, making the results directly applicable to strategic decision-making. These characteristics make UFPA a representative example of the growing segment of public universities seeking to reduce operational costs through market liberalization.

Model Validation. To ensure the reliability of the simulation results, the proposed financial model was validated against historical electricity invoices. Specifically, the regulated market costs estimated by the model (ACR scenario) were compared with the actual invoice values recorded over the reference period. The relative error between simulated and actual values remained below 2% across all consumer units analyzed, confirming the adequacy of the model for projecting costs under both the regulated and deregulated scenarios. This validation step strengthens confidence in the projected savings reported for Modalities M1 and M2.

- **Modality 1 (M1):** For M1, a guaranteed discount of 22.2% was assumed on the final amount charged (R\$) based on the history of monthly invoices received from the utility.
- **Modality 2 (M2):** For M2, a fixed Energy Tariff (TE) was assumed for each year of the contract term. For the Distribution System Usage Tariff (TUSD), a 50% discount was applied depending on the consumer unit's tariff modality.

In Brazil, energy from small hydroelectric plants, hydroelectric plants up to 1 MW, or renewable sources such as solar, wind, or biomass with injected power of up to 30 MW can receive discounts of 50% to 100%. For the M2 scenario, the energy to be contracted was considered to be from a 50% incentivized source, based on the proposals received. Furthermore, 50% incentivized energy offers greater liquidity in the energy market and a lower total cost compared to other types. In addition, the results (in R\$) presented for each simulation consider the taxes applied (Social Integration Program - PIS, Contribution for the Financing of Social Security - COFINS and Tax on Circulation of Goods and Provision of Services - ICMS), aiming to simulate the final energy costs closest to a real scenario, in order to compare with the values of the regulated contracting environment (ACR).

III. ENERGY MANAGEMENT DASHBOARD

The system developed to manage and optimize the energy consumption of the university's consumer units consists of several integrated stages, as presented in Figure 4. These stages ensure an automated and efficient workflow. The methodology can be divided into three main phases: data collection and processing, storage, and visualization and reporting.

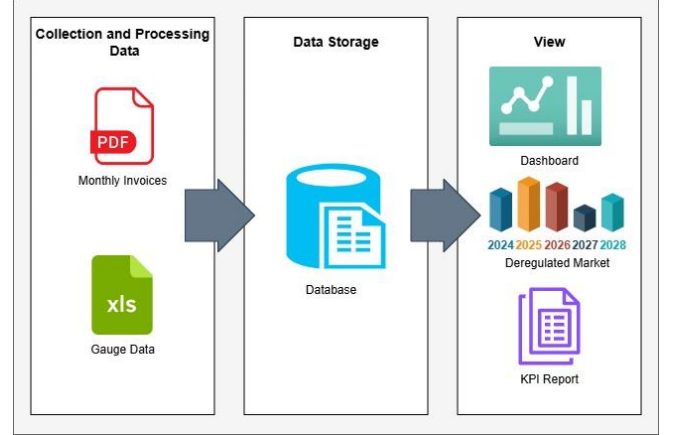


Fig. 4. Methodology for the management platform development

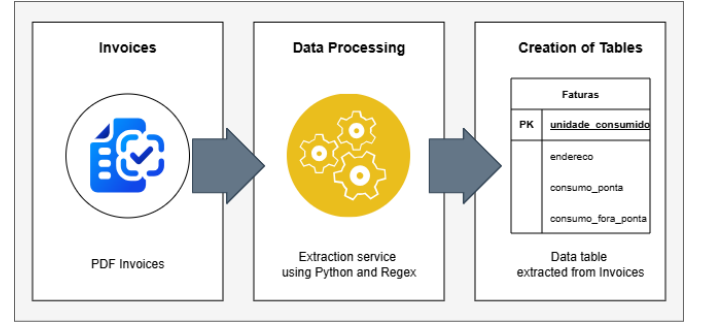


Fig. 5. Example of processing of energy bill data in PDF format, with highlighting of automatically extracted information.

A. Data capture and extraction from PDF energy bills

The initial step involved automating the collection of electricity bill data in PDF format. Accurate extraction was essential to feed the database for subsequent analysis and visualization. The PyMuPDF library was used to read the files, extracting the complete text as a base for identifying relevant information. Regular expressions (regex) were then applied to capture specific patterns, ensuring precision in the process. The extracted data included consumer unit details (code, voltage, address, municipality), bill information (issue date, read period, due date), consumption and demand values (kWh by peak/off-peak, contracted and measured demand, tariffs), as well as taxes and fees (PIS, COFINS, ICMS, tariff flags, demand overruns). Additional values such as withholding taxes (IRPJ and CSLL) were also identified, providing a comprehensive view of energy costs. The process is presented in Figure 5.

B. Data Storage

The extracted data was organized into a dictionary, each key representing a category of information (e.g., "consumption in kWh at peak" or "ICMS value"). This dictionary was converted into a DataFrame using the Pandas library due to its efficient manipulation capabilities and ease of data analysis and storage. Once the data was organized in a DataFrame, it was inserted into a relational database using SQLite, chosen for its simplicity and efficiency in storing tabular data. Each invoice was inserted as a new entry in a specific table in the database, with columns corresponding to the different categories of data extracted. This database forms the basis for all subsequent analyses, allowing comparison, aggregation, and integrated visualization of data from multiple invoices.

C. Data Visualization and Analysis

Once the data was extracted and stored, it was used to create interactive dashboards and perform detailed analysis. These tools made it possible to visualize consumption patterns, identify trends, and optimize energy demand. The platform, presented in Fig. 6, uses Streamlit to create an interactive visualization interface that allows managers to access and analyze consumption and demand data. The dashboards developed in Streamlit feature detailed graphs such as consumption trend lines, bar charts comparing different

consumer units, and heat maps to identify seasonal patterns. These dashboards are essential for managers to identify optimization opportunities as they transition to the deregulated energy market. In addition to viewing historical data, the interface allows users to run simulations of different demand scenarios to aid in strategic decision-making.

The platform developed in this study shares conceptual similarities with SISGEE [13], a multi-platform energy management system also developed in the Brazilian Amazon context. However, while SISGEE focuses on real-time monitoring through installed meters and is designed primarily for power quality and energy efficiency studies within a single institution, the platform presented here addresses a distinct operational need: the automated extraction and processing of billing data from PDF invoices across multiple consumer units, combined with market migration simulation capabilities. This distinction is significant, as the proposed tool targets the pre-migration decision phase, enabling managers to assess financial scenarios before committing to a free market contract, rather than post-migration operational monitoring. To the best of the authors' knowledge, no existing published tool integrates PDF-based invoice parsing, multi-unit consumption aggregation, and deregulated market simulation within a single decision-support environment tailored for qualified consumers in Brazil

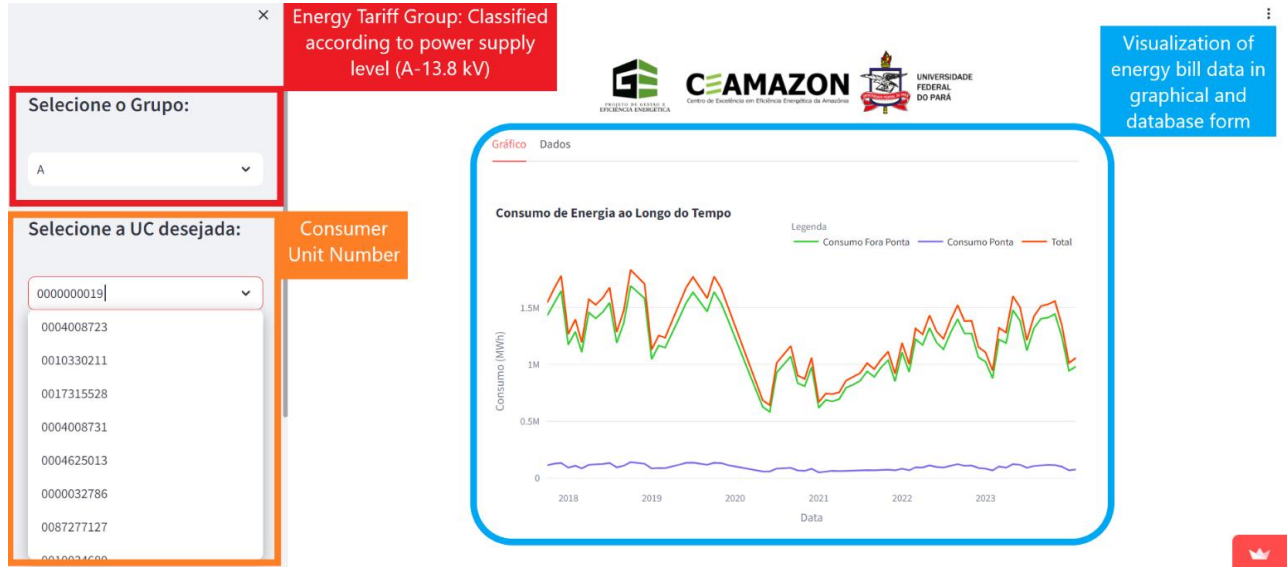


Fig. 6. Graphical visualization of the dashboard developed for the study

IV. RESULTS AND DISCUSSION

Typically, contracts in the Free Contracting Environment (ACL) have a five-year term; this period was selected to compare estimated values with ACR costs. Both modalities were tested in the migration study.

For M1, the final invoice value derives from a 22.2% discount.

For M2, the TE value is shown in Table I, based on average quotes over five years.

A 5% adjustment rate was assumed. Based on these considerations, scenarios M1 and M2 were compared with ACR values. Table II presents the annual and total cost comparison.

Scenario M2 offers the lowest overall cost. Compared to the ACR, the estimated savings for five years are R\$35,443,411.94. Although results indicate significant economic benefits, it is important to acknowledge risks of market liberalization.

Energy costs in the ACL are subject to spot market variations, regulatory adjustments, and macroeconomic factors such as inflation and exchange rates. Changes in TE or adjustment rates may affect projected savings. Unexpected reforms—such as tariff-discount modifications or renewable-energy incentive changes—may also affect performance. Therefore, sensitivity analyses that account for tariff variability, inflation, and regulatory scenarios are essential to ensure robust

decision-making and mitigate risks for qualified consumers migrating to the deregulated market. To address this, the following subsection presents a structured sensitivity analysis grounded in the historical billing data of the institution.

A. Sensitivity Analysis

To assess the robustness of the projected savings, a sensitivity analysis was performed using historical tariff data from the UFPA billing records spanning 2021–2025, which revealed an average annual energy tariff variation of +0.59% with a standard deviation of $\pm 7.98\%$. Based on this empirically observed range, three scenarios were defined: a pessimistic case (10% reduction in ACR costs combined with a 10% worsening of ACL contracted conditions), the base case as presented, and an optimistic case (10% increase in ACR costs with a 10% improvement in ACL conditions). Table III summarizes the five-year results under each scenario.

Even under the most conservative scenario, Modality M2 yields savings of approximately R\$ 13.9 million over five years compared to the regulated market, confirming that the economic advantage of migration is preserved even under adverse tariff conditions. These results reinforce the financial case for migration while highlighting that the magnitude of savings is sensitive to market dynamics. Decision-makers should therefore monitor annual tariff adjustments, inflation indices, and regulatory changes throughout the contract period to ensure that projected benefits are realized.

TABLE I. TE PER M2 FOR A 5-YEAR CONTRACT WITHOUT ANNUAL ADJUSTMENT

Effective Year	TE Price for M2 (R\$/MWh)
1	278.2
2	250.42
3	240.35
4	227.44
5	221.90

TABLE II. ANNUAL COST COMPARISON BETWEEN ACR, M1, AND M2

Year	ACR Value (R\$)	M1 (R\$)	M2 (R\$)
1	25,133,548.84	19,553,901.00	18,354,616.32
2	25,133,548.84	19,553,901.00	17,898,938.95
3	25,133,548.84	19,553,901.00	17,960,004.76
4	25,133,548.84	19,553,901.00	17,909,367.96
5	25,133,548.84	19,553,901.00	18,101,404.27
Total	125,667,744.21	97,769,504.99	90,224,332.26

TABLE III. SENSITIVITY ANALYSIS: FIVE-YEAR COST COMPARISON UNDER THREE TARIFF SCENARIOS

Scenario	ACR (R\$)	M1 (R\$)	M2 (R\$)	Savings M2 vs. ACR (R\$)	Savings (%)
Pessimistic	113,100,969.79	107,546,455.49	99,246,765.49	13,854,204.30	12.2 %
Base Case	125,667,744.21	97,769,504.99	90,224,332.26	35,443,411.95	28.2 %
Optimistic	138,234,518.63	87,992,554.49	81,201,899.03	57,032,619.60	41.3 %

V. THE HONDURAS POWER SYSTEM PERSPECTIVE

A. Honduras Electricity Market

The General Law of the Electricity Industry (LGIE), approved through Decree No. 404-2013 and published in the Official Gazette La Gaceta on May 20, 2014, along with its amendments through Decrees 61-2020, 02-2022, and 46-2022, aims to regulate the activities of the electricity subsector within the territory of the Republic of Honduras.

In accordance with the LGIE, the National Electricity Market (MEN) is a wholesale market, managed by the System Operator, consisting of a set of electricity purchase and sale transactions carried out by MEN agents through the Contract Market and the Opportunity Electricity Market (MEO) [26].

The Regulation of the LGIE (RLGIE) establishes that MEN agents are divided into producer agents (generation companies) and purchaser agents (distribution companies and qualified consumers that choose to participate in the MEN). Article 10 of the LGIE states that qualified consumers acting as MEN agents must have contracted sufficient firm capacity to cover the percentage of their maximum power demand above 5 MW [27].

B. Impact on Generation Costs for Qualified Consumers as MEN Agents

The RLGIE stipulates that qualified consumers acting as MEN agents must contract, for the following 12 months, firm capacity sufficient to cover 75% of their firm power requirement. This means that such consumers may purchase the remaining 25% of their power requirement from the MEO to ensure an adequate and secure electricity supply [27].

According to the RLGIE, in the Contract Market, qualified consumers participating in the MEN (excluding distribution companies) may enter into firm capacity and energy contracts at freely agreed prices. Regarding the Opportunity Market, the RLGIE establishes that in this market, short-term electricity prices are determined for each Market Period (hourly) and at each node of the Main Transmission System based on the economic dispatch of generation units. Concerning the price of capacity, the LGIE establishes that in the MEO this value is set at 8.78 USD/kW-month [27]. Based on this framework, a qualified consumer who opts to become a MEN agent, obtaining firm capacity and energy through a combination of the Contract Market and the MEO, could achieve a lower total electricity supply cost (including capacity and energy) compared to the generation costs offered by the National Electric Power Company (ENEE) under regulated tariffs. This is supported by the fact that, according to the Electricity Regulatory Commission (CREE), generation costs represent 67% of the electricity tariff. It should be noted that, in addition to the specific costs associated with electricity supply, these users must also assume other charges related to the service, such as distribution and transmission tolls, the operation and administration of the MEN and the Regional Electricity Market, payments for ancillary services, and other expenses inherent to electricity service [28].

C. Legal Framework Analysis of Qualified Consumers as MEN Agents

To enable the participation of qualified consumers in the MEN, it is imperative to have clear rules that allow both the technical and legal deployment of this type of agent, which must be developed by the CREE and the System Operator through regulations. After reviewing the current regulatory framework in Honduras and considering the obligations and rights of qualified consumers opting to become MEN agents, it is concluded that this framework consists of 13 regulatory elements: LGIE, RLGIE, Wholesale Market Operation and Administration Regulation (ROM), Tariff Regulation (RT), Public Lighting Regulation (RT-AP), Technical Standard for Access, Connection, and Use of the Transmission Network (NT-AUCTE), Technical Settlement Standard (NT-LL), Technical Standard for the Opportunity Electricity Market (NT-MEO), Technical Standard for Firm Capacity (NT-PF), Technical Standard for Contracts (NT-CC), Technical Standard for Settlements in the Opportunity Electricity Market (NT-LMEO), Technical Standard for Commercial Measurement (NT-MC), and Technical Standard for Ancillary Services (NT-SSCC) [29]. Figure 7 shows the regulatory instruments currently in force and those under development that establish the obligations and rights of qualified consumers opting to act as MEN agents. The figure highlights that the published regulations cover a large portion of the obligations and rights of qualified consumers. However, based on the number of obligations and rights under development, the NT-LL requires more urgent publication due to its implications for regulating this type of agent.

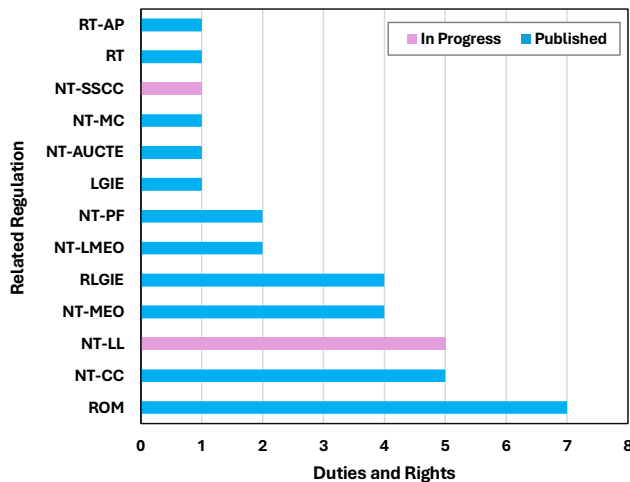


Fig. 7. Obligations and rights according to the regulation:

D. Benefits of Qualified Consumer Participation in the MEN

According to CREE, the MEN currently has one qualified consumer participating as a MEN agent and ten qualified consumers who are registered but have not opted to act as MEN agents. In this regard, the MEN is characterized as a monopsony, with ENEE operating practically as the sole purchaser agent [27], [28]. Increasing the participation of qualified consumers in the MEN could drive the entry of new producer agents, thereby reducing

market concentration and fostering a more competitive market, which in turn would lead to:

- **Flexibility:** Greater flexibility for buyers and sellers, while significantly influencing the operation and reliability of the National Interconnected System. Furthermore, market liberalization introduces stronger competition in the electricity sector, aiming to achieve greater efficiency that benefits both users and producers.
- **Investment incentives:** A larger number of qualified consumers able to freely contract capacity and energy improves conditions for attracting greater investment in the sector, contributing to the modernization and expansion of the MEN. With higher levels of private investment in the electricity subsector, significant amounts of public spending could be redirected toward critical social needs such as health, education, housing, and security.

The Brazilian case study presented in this work offers a concrete reference point for quantifying these potential benefits. At UFPA, a large public institution with consumption characteristics comparable to qualified consumers eligible for the Honduran MEN (demand above 5 MW), migration to the deregulated market under Modality M2 yielded average savings of 28.2% compared to the regulated tariff over a five-year horizon. If a similar margin were achievable for Honduran qualified consumers — even partially, given the structural differences between both markets — the financial case for participation in the MEN would be substantial. Currently, generation costs represent 67% of the electricity tariff in Honduras, according to CREE [27], [28], which is precisely the component that qualified consumers can negotiate freely in the Contract Market. This structural similarity reinforces the transferability of the Brazilian findings and underscores the importance of advancing the regulatory and technical conditions necessary for broader MEN participation.

E. Challenges Facing the Honduran Electricity Subsector in Increasing Qualified Consumer Participation in the MEN

Some of the challenges faced by Honduras in fostering greater participation of qualified consumers within the MEN include:

- **Robust regulatory framework:** The framework must be strong, reflecting stability, while allowing lessons from its application to guide necessary improvements.
- **Experience and knowledge:** Training must be provided to enable stakeholders to fully understand the regulations applicable to this type of agent.
- **Security and confidence:** It is necessary to foster greater security and confidence for qualified consumers to actively participate in the MEN, thereby promoting competition and efficiency in the market. This requires encouraging the participation of intermediaries between qualified consumers and MEN producer agents. Such intermediaries, acting as independent expert entities, could provide comprehensive advice and support to qualified consumers regarding electricity market operations, tariff comparisons among suppliers, contract review and negotiation, efficient energy management, supply diversification (via contracts or spot purchases), and the adoption of technological innovations in the energy sector.

VI. FINAL CONSIDERATIONS

This study demonstrated that the migration of qualified consumers to the deregulated electricity market in Brazil can generate substantial economic benefits while supporting renewable energy procurement. The case study revealed that:

- A fixed discount model (22.2%) results in an estimated 27.9 million BRL savings over five years compared to the regulated environment.
- A contractual model with incentivized renewable energy and TUSD discounts yields the greatest advantages, achieving average savings of 28.2% and a total reduction of 35.4 million BRL over five years.

Beyond financial benefits, migration to the free contracting environment provides additional value by ensuring renewable energy procurement, improving budget predictability, and strengthening institutional sustainability goals.

From the Honduran perspective, the analysis highlights that while the regulatory framework establishes the foundation for qualified consumer participation, several challenges persist, including high minimum demand thresholds, incomplete technical standards, and limited consumer confidence. Addressing these barriers is essential for Honduras to replicate the positive outcomes observed in Brazil, foster competition, and attract private investment.

Limitations and Future Work. This study has certain limitations that should be acknowledged. First, the financial projections are based on a single institutional case study, which limits the generalizability of the quantitative results to other consumer profiles, sectors, or regions. Second, the sensitivity analysis relies on parametric scenarios rather than probabilistic modeling; future work could adopt stochastic methods to better capture the full distribution of possible outcomes under market uncertainty. Third, the platform was developed and tested within the UFPA institutional context; its applicability to other billing formats or regulatory environments would require adaptation and further validation. Future research directions include: (i) extending the migration framework to multiple qualified consumers across different sectors to enable cross-case comparison; (ii) incorporating machine learning models for energy consumption forecasting within the platform; and (iii) applying the proposed framework to the Honduran context once the pending technical standards, particularly the NT-LL, are formally published.

REFERENCES

- [1] OECD, *Competition in Electricity Markets*. Paris: Organisation for Economic Co-operation and Development, 2001. Accessed: Aug. 25, 2024. [Online]. Available: https://www.oecd-ilibrary.org/energy/competition-in-electricity-markets_9789264192768-en
- [2] N. Fatras, Z. Ma, H. Duan, and B. N. Jørgensen, "A systematic review of electricity market liberalisation and its alignment with industrial consumer participation: A comparison between the Nordics and China," *Renew. Sustain. Energy Rev.*, vol. 167, p. 112793, Oct. 2022, doi: 10.1016/j.rser.2022.112793.
- [3] W. Hogan, "On an 'Energy Only' Electricity Market Design for Resource Adequacy," Jan. 2005.
- [4] M. R. Basnet, J. A. Bryan, S. J. Dana, A. S. Meek, H. Wang, and P. Talbot, "Stochastic Optimization and Uncertainty Quantification of Sodium-based Nuclear-Renewable Energy Systems for Flexible Power Applications in Deregulated Markets," *Appl. Energy*, vol. 375, p. 124105, Dec. 2024, doi: 10.1016/j.apenergy.2024.124105.
- [5] P. L. Joskow, "Lessons Learned From Electricity Market Liberalization," *Energy J.*, vol. 29, no. 2_suppl, pp. 9–42, Dec. 2008, doi: 10.5547/ISSN0195-6574-EJ-Vol29-NoSI2-3.
- [6] S. Borenstein and J. Bushnell, "The U.S. Electricity Industry After 20 Years of Restructuring," Apr. 2015, *National Bureau of Economic Research*: 21113. doi: 10.3386/w21113.
- [7] H.-A. I. El-Azab, R. A. Swief, N. H. El-Amry, and H. K. Temraz, "Machine and deep learning approaches for forecasting electricity price and energy load assessment on real datasets," *Ain Shams Eng. J.*, vol. 15, no. 4, p. 102613, Apr. 2024, doi: 10.1016/j.asej.2023.102613.
- [8] S. K. Aggarwal, L. M. Saini, and A. Kumar, "Electricity price forecasting in deregulated markets: A review and evaluation," *Int. J. Electr. Power Energy Syst.*, vol. 31, no. 1, pp. 13–22, Jan. 2009, doi: 10.1016/j.ijepes.2008.09.003.
- [9] R. Weron, "Electricity price forecasting: A review of the state-of-the-art with a look into the future," *Int. J. Forecast.*, vol. 30, no. 4, pp. 1030–1081, Oct. 2014, doi: 10.1016/j.ijforecast.2014.08.008.
- [10] D. A. Lima and D. N. T. Paula, "Free contract environment for big electricity consumer in Brazil considering correlated scenarios of energy, power demand and spot prices," *Electr. Power Syst. Res.*, vol. 190, p. 106828, Jan. 2021, doi: 10.1016/j.epr.2020.106828.
- [11] R. R. B. Silva, A. C. P. Martins, E. M. Soler, E. C. Baptista, A. R. Balbo, and L. Nepomuceno, "Two-stage stochastic energy procurement model for a large consumer in hydrothermal systems," *Energy Econ.*, vol. 107, p. 105841, Mar. 2022, doi: 10.1016/j.eneco.2022.105841.
- [12] J. Arellano and M. Carrión, "Electricity procurement of large consumers considering power-purchase agreements," *Energy Rep.*, vol. 9, pp. 5384–5396, Dec. 2023, doi: 10.1016/j.egyr.2023.04.371.
- [13] I. S. de Carvalho, U. C. P. Júnior, F. Monteiro, M. Tostes, J. R. da S. Muniz, and A. C. D. B. de Souza, "Modelagem e validação de um sistema multiplataforma para Gerenciamento de Energia Elétrica – SISGEE." Accessed: Jul. 12, 2024. [Online]. Available: <https://proceedings.science/sbai-2019/trabalhos/modelagem-e-validacao-de-um-sistema-multiplataforma-para-gerenciamento-de-energia?lang=pt-br>
- [14] M. E. de Lima Tostes *et al.*, "Aplicação dos objetivos do desenvolvimento sustentável na Amazônia: um estudo de caso na Universidade Federal do Pará (UFPA)," *Peer Rev.*, no. 20, pp. 365–379, Oct. 2023, doi: 10.53660/1073.prw2627.
- [15] A. C. D. B. de Souza *et al.*, "Impact of Electric Vehicles Consumption on Energy Efficient and Self-Sufficient Performance in Building: A Case Study in the Brazilian Amazon Region," *Energies*, vol. 17, no. 16, Art. no. 16, Jan. 2024, doi: 10.3390/en17164060.
- [16] J. M. Tabora *et al.*, "Hybrid System Assessment in On-Grid and Off-Grid Conditions: A Technical and Economical Approach," *Energies*, vol. 14, no. 17, Art. no. 17, Jan. 2021, doi: 10.3390/en14175284.
- [17] B. K. Tshombe, J. Muñoz Tabora, W. da Silva Fonseca, M. Emília Lima Tostes, and E. O. de Matos, "Voltage Harmonic Impacts on Line Start permanent Magnet Motor," in *2021 14th IEEE International Conference on Industry Applications (INDUSCON)*, Aug. 2021, pp. 962–968. doi: 10.1109/INDUSCON51756.2021.9529539.
- [18] J. M. Tabora, M. E. de Lima Tostes, E. O. de Matos, and U. H. Bezerra, "Voltage Unbalance & Variations Impacts on IE4 Class LSPMM," in *2021 14th IEEE International Conference on Industry Applications (INDUSCON)*, Aug. 2021, pp. 940–946. doi: 10.1109/INDUSCON51756.2021.9529505.
- [19] J. M. Tabora *et al.*, "Virtual Modeling and Experimental Validation of the Line-Start Permanent Magnet Motor in the Presence of Harmonics," *Energies*, vol. 15, no. 22, Art. no. 22, Jan. 2022, doi: 10.3390/en15228603.
- [20] N. Mendes *et al.*, "ANN for Motor Loading Diagnosis under Voltage Variation Conditions," in *2023 IEEE Kansas Power and Energy Conference (KPEC)*, Apr. 2023, pp. 1–6. doi: 10.1109/KPEC58008.2023.10215414.
- [21] A. M. Carreiro, H. M. Jorge, and C. H. Antunes, "Energy management systems aggregators: A literature survey," *Renew. Sustain. Energy Rev.*, vol. 73, pp. 1160–1172, Jun. 2017, doi: 10.1016/j.rser.2017.01.179.
- [22] J. Sánchez, A. Salgado, A. García, and N. Monzón, "IDSEM, an invoices database of the Spanish electricity market," *Sci. Data*, vol. 9, no. 1, p. 786, Dec. 2022, doi: 10.1038/s41597-022-01885-3.
- [23] H. P. Burin, J. C. M. Siluk, and C. B. Rosa, "A model to measure the migration potential of Brazilian consumers from the regulated market

- to the free energy market,” *Energy Sustain. Dev.*, vol. 70, pp. 403–414, Oct. 2022, doi: 10.1016/j.esd.2022.08.012.
- [24] M. Hochberg and R. Poudineh, “The Brazilian electricity market architecture: An analysis of instruments and misalignments,” *Util. Policy*, vol. 72, p. 101267, Oct. 2021, doi: 10.1016/j.jup.2021.101267.
- [25] “Ministério de Minas e Energia, ‘Portaria Normativa No. 50/GM/MME, de 27 de setembro de 2022,’ Diário Oficial da União, Brasília, Brazil, Seção 1, p. 188, Sep. 28, 2022. [Online]. Available: <https://www.gov.br/mme/pt-br/aceso-a-informacao/legislacao/portarias/2022/portaria-normativa-n-50-gm-mme-2022.pdf>.”
- [26] “National Congress of Honduras, General Law of the Electricity Industry, Decree No. 404-2013, Official Gazette La Gaceta, No. 33,431, Tegucigalpa, Honduras, May 20, 2014.”
- [27] “Regulatory Commission of Electric Power (CREE), Regulation of the General Law of the Electricity Industry, Agreement CREE-073-2020, Official Gazette La Gaceta, No. 35,301, Tegucigalpa, Honduras, July 2, 2020.”
- [28] “Histórico de Informes - Ajuste al Costo Base de Generación,” CREE. Accessed: Aug. 21, 2025. [Online]. Available: <https://www.cree.gob.hn/historico-de-informes/>
- [29] “Leyes, Reglamentos, Normas Técnicas y Procedimientos,” CREE. Accessed: Aug. 21, 2025. [Online]. Available: <https://www.cree.gob.hn/leyes-reglamentos-y-normas-tecnicas/>