FREE ENERGY MARKET TRANSITION: A CASE STUDY OF 32 CONSUMER UNITS IN BRAZIL

Anderson Azevedo Fraga[1], Sabrina Antonio Torres[1], Charles Dias de Almeida[2], Henrique Ferrario Traba[1], Lohane Barcelos Palaoro[1], Guilherme Henrique Pereira[3] and Marcelo Eduardo Vieira Segatto[1]

[1] Federal University of Espírito Santo, Vitória (Brazil)

[2] Sustainable Energy Management Laboratory - Government of Espírito Santo, Vitória (Brazil)

[3] Arandu Institute, Vitória (Brazil)

Abstract

Given the growing consumption for energy, electricity represents a significant share in the public budget, particularly for the Government of Espírito Santo, approximately 12.46% of the total administrative expenses of the units. Based on this, the present study analyzes the feasibility of migrating Consumer Units of the Executive Branch of the State of Espírito Santo to the Free Contracting Environment, aiming for economic and sustainable gains. Thirty-two units were selected for a case study, based on consumption and demand data between 2024 and 2025, to project future consumption and costs. The analysis considered 32 Consumer Units, including the procurement of 1.25 MW average from conventional and renewable energy sources, indicating a potential savings of up to 30.54%. Although there are challenges characteristic of public administration, in contrast to management in the private sector, particularly due to national and subnational legal frameworks to which it is subject, the results indicate that migration is technically and economically feasible. This positions the Free Contracting Environment as a strategic alternative for optimizing public resources and meeting environmental goals, aligned with the Sustainable Development Goals and the long-term strategic plan entitled "*ES 500 anos*".

Keywords: Free Contracting Environment; Retail Electricity Market; Public Services; Electricity

1. Introduction

The Brazilian electricity sector underwent a major reform driven by growing energy demand and limited investment for its expansion. This reform allowed the entry of private companies into a sector that was previously the exclusive domain of state-owned companies, a process called unbundling (*desverticalização*). The main change was to separate the different stages of power supply into generation and commercialization, which were opened to free competition among various companies, while transmission and distribution remained as regulated services provided by a single company in each region. This new configuration changed the role of the State, which shifted from being an investor to a regulator, and allowed the emergence of new agents such as independent power producers, energy traders, and free consumers (CCEE, 2019; Santos et al., 2021; Silva et al., 2023).

With Law No. 9,074 of 1995, the purchase and sale of electricity in Brazil began to operate as a market, allowing some consumers to choose their supplier. However, the rules for migrating to this new environment were restricted to consumers with a demand exceeding 3000 kW. To organize the negotiations, the Wholesale Electricity Market (*Mercado Atacadista de Energia* – MAE) was established, which operated under a self-regulatory model where the rules would be defined by the market participants themselves. In parallel, the National System Operator (*Operador Nacional do Sistema* – ONS) became responsible for ensuring the security of the grid's physical operation, alongside the Electric Sector Monitoring Committee (*Comitê de Monitoramento do Setor Elétrico* – CMSE) and the National Electric Energy Agency (*Agência Nacional de Energia Elétrica* – ANEEL), responsible for regulating and overseeing the entire sector (Brazil, 1995; Brazil, 1998; Prado, 2006).

The energy crisis in 2001 demonstrated that the previous market model failed to incentivize the expansion of electric power generation, partly due to flaws in the supply guarantee criteria that discouraged new

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investment. Law No. 10,848 of 2004 established the "New Model", which reinstated long-term government planning as the basis for ensuring supply, representing a response to the failures of the previous model. The main contracting tool created, regulated by Decree No. 5,163, was auctions, in which power generation companies compete for price to secure long-term contracts in the Regulated Contracting Environment. The market was then divided into two settings: the "Regulated Contracting Environment" (*Ambiente de Contratação Regulada* – ACR, or RCE), for captive consumers, and the "Free Contracting Environment" (*Ambiente de Contratação Livre* – ACL, or FCE), for large consumers. Furthermore, to ensure expansion, distribution companies were required to contract 100% of their demand (MME, 2019; Brazil, 2004a; 2004b; 2004d).

To execute the long-term planning determined by the New Model, the Energy Research Company (*Empresa de Pesquisa Energética* – EPE) was created, with the purpose of conducting studies and research that serve as the basis for the sector's expansion planning. Additionally, the old Wholesale Electricity Market (MAE) was replaced by the Electric Energy Trading Chamber (*Câmara de Comercialização de Energia Elétrica* – CCEE), the entity responsible for enabling and managing the purchase and sale operations. This structure consolidated the operational difference between the two environments: in the RCE, the price of energy is defined by auctions and passed on to captive consumers through tariffs regulated by ANEEL; in the FCE, consumers freely negotiate with generators and traders (Brazil, 2004c; Brazil, 2004d; ANEEL, 2022; ABRACEEL, 2023). Rising global energy demand, driven by industry and electrification, behaves differently across economies. In developing nations like Brazil, electricity consumption grows directly with GDP, fueled by industrial expansion and increased household use (IEA, 2025).

According to data from the Energy Information Administration (EIA), Brazil ranks as the sixth country with the highest electricity consumption, representing approximately 608 billion kWh. The Statistical Yearbook of Electricity of 2024, prepared by the EPE, details the participation of the federative entities from a regional and sectoral perspective, highlighting the role of the Brazilian state of Espírito Santo and its public sector. In the national scenario, the Southeast region leads consumption, accumulating about 48% of the Brazilian total. In the regional context, specifically considering the subnational entities of the Southeast, Espírito Santo contributes 4.65% of the amount, equivalent to 11,639 GWh, with 2.7% of this value represented by the public sector, which shows a 12% growth compared to the previous year — the highest increase among all classes (EPE, 2024; 2025).

Given that electricity is one of the largest administrative expenses, Brazilian public entities have adopted measures to reduce costs, such as the tariff readjustment provided for in Article 4, Section I, of Decree No. 8,540/2015, which guides the review of contracted demand (ME, 2015). However, promising new alternatives, such as the Retail Electricity Market, still relatively new in the public sector, emerge with the same proposal and may prove to be more efficient. Thus, there is a trend of expanding consumption by public entities, which are significantly impacted by the increased provision of public services to citizens, with the installation of numerous electricity-consuming equipment, such as large data centers, hospital units, prison systems, and public schools — particularly due to air conditioning in classrooms, as a prerequisite for better teaching-learning environments. In this scenario, the need arises for studies that evaluate alternatives and the feasibility of cost optimization, considering technical, economic and, above all, sustainability issues (TCU, 2024; EPE, 2024).

This study focus on analyzing the feasibility and implementation of sustainable energy procurement in the Free Contracting Environment for the medium-voltage Consumer Units (*Unidades Consumidoras* – UCs, or CUs) of the Executive Branch of the State of Espírito Santo. The main objective is to document the minimum procedures leading to this analysis and its results regarding the evaluation of migration conditions. For this purpose, a case study was conducted involving 32 Group-A CUs, specifically the A4, with voltage service ranging from 2,3 kV up to 25 kV, and B3 subgroup for public sector buildings, "Green" hourly modality. This migration analysis of the CUs is also strongly based on two factors: environmental — considering sustainable solutions, with the priority adoption of low-impact renewable energies; and economic-financial, which aims to generate significant savings in one of the state's main administrative expenses, as organized in Table 1.

Table 1: Proportion of the expenditure on electricity by state unit over the total of major administrative expenses, in US dollars.

Administration expenses for the unit from Jan 1st of 2024 to Dec 31st of 2024, in USD					
Description	Committed	Settled	Paid	Outstanding Balance Paid	Total Paid + OBP
Total	120,628,882.00	110,922,979.59	106,004,603.69	12,749,350.58	118,768,757.78
Electricity expenses from Jan 1st of 2024 to Dec 31st of 2024, in USD					
Description	Committed	Settled	Paid	Outstanding Balance Paid	Total Paid + OBP
Total	15,169,284.21	13,667,977.28	13,517,965.31	1,277,054.88	14,795,020.18
Proportion	12.57%	12.32%	12.75%	10.02%	12.46%

In this context, this work outlines the advantageous aspects and potential technical challenges involved in the process of migrating the energy matrix of the Executive Branch of the State of Espírito Santo, highlighting the initiative to make public services more efficient and sustainable.

2. Free Contracting Environment

The parameters for assessing migration potential of Consumer Units to the free electricity procurement modality are defined by current legislation. Thus, since 1994, with the Electric Sector Restructuring Project, as well as Law No. 9,074/95 and Decree No. 5,163/04, the Free Contracting Environment was created, as discussed in introduction section, allowing consumers to become free to contract electric energy, providing for those with energy demand equal to or greater than 500 kW. In 2019, there was a revision of the limits characterizing potentially free consumers, where, through Ordinance 465/2019, published by the Ministry of Mines and Energy at the time, consumers were categorized starting in 2021 according to their demand – 1500 kW, 1000 kW, and 500 kW (Brazil, 1995, 2004, 2019).

In this way, following the conception of the CCEE, established by ANEEL in 2004, the Free Contracting Environment was created, aligned with the Commercialization Rules and Procedures, a document containing the guidelines governing energy trading in this environment, published by the CCEE (ANEEL, 2004; Brazil, 2004a). To facilitate the understanding of the scenarios outlined for this study, the main characteristics of the FCE, considered relevant for the outcome of this study, are presented in a summarized and direct manner.

2.1 Free Contracting Environment characteristics

With the CCEE creation, it became possible to implement electrical energy trading, involving the management of contracts between consumers, traders, and generators. Contracts signed between interested parties in the FCE, called CCEAL (*Contrato de Comercialização de Energia no Ambiente de Contratação Livre* or Free Contracting Environment Energy Commercialization Contract) — whether between consumers and traders, traders and generators, or even between traders — are handled according to the demands of each party. These contracts stipulate the contract term, the amount and type of energy to be settled, unit prices and volume of electricity traded, rights and duties of each interested party, among other parameters. For this purpose, these contracts are established within time horizons ending in long-term intervals, starting from 5 years or longer, and in some cases, short-term intervals within a year. In some cases, due to adverse circumstances related to the contract terms, there is a possibility that the agreed amounts of energy supply and generation may not be honored, thus requiring compliance measures to mitigate negative exposure (CCEE, 2022a).

This calculated price, called the Difference Settlement Price (*Preço de Liquidação de Diferenças* – PLD, or DSP), is used to determine the value of the energy volumes settled at the CCEE, serving as a reference for all transactions within the FCE. This value is published by the Trading Chamber at hourly intervals, along with the Marginal Operation Cost (*Custo Marginal de Operação* – CMO), combining cost optimization based on simulations forecasting weather conditions and other environmental variables. These data are interpreted via computational simulations using mathematical models to project values over a pre-determined period. For example, one of the models used by the CCEE, NEWAVE, measures long-term horizon scenarios. Like other models that enable granular monthly forecasts, it facilitates daily price values, in every hour, by the CCEE (CCEE, 2023; Junior et al., 2024).

Unlike how electricity values are determined in the RCE, market prices are values practiced by electricity traders in the FCE, with the valuation basis determined by the DSP. Thus, consumers participating in the FCE are represented by agents associated with the CCEE, who act as intermediaries in the energy sale and purchase between end-consumers and generators, as well as requiring this traded energy value for the end-consumer. These actors assume roles such as wholesale and retail traders, with this distinction being restricted to the amounts of energy sold by each within a period (CCEE, 2025; ANEEL, 2022a).

The trade conducted by the CCEE aims to organize, clarify, and record the exchange of goods—in this case, electrical energy between stakeholders, who must necessarily comply with current regulations. Additionally, the interested parties are required to ensure financial capacity, especially traders, to guarantee that contractual obligations are honored through financial guarantees backed by assets. The CCEE ensures, as one of its responsibilities, the financial settlement of these contracts between parties through contractual guarantees or via the Short-Term Market (*Mercado de Curto Prazo* – MCP) (Castro and Matsumura, 2021).

Finally, to reinforce the analyses carried out, it is necessary to differentiate the types of energy traded in the FCE, primarily to characterize the main aspect of differentiation from the RCE. In this environment, the energy sources are not entirely from renewable sources, which reduces the global advantages of energy acquisition in the FCE when compared to RCE. The energies traded are divided into Conventional Energy, from traditional sources that do not have specific subsidies or incentives attached; and Incentivized Energy, or Green Energy, which receives fiscal incentives along with certificates attesting energy production from renewable sources, comprising the amount of electricity from a sustainable energy matrix, ranging from 50% to 100% discount, aimed at promoting the expansion of it (Brazil, 2004b; CCEE, 2023).

2.2 Modalities, taxes and charges

The data over simulated scenarios were handled to determine how advantageous the migration process is, regarding the modality, tariffs, and charges. Thus, for definition purposes, the modalities considered for this evaluation are the Green and Blue Hourly Tariff Modalities, both referring exclusively to Consumer Units belonging to tariff Group A, with service voltage of 2,3 kV or above, and which result in different values for the final cost of the traded electricity. Both modalities consider tariffs with discounts for energy consumption and demand, differing only in the single demand tariff charge for the Green Hourly Tariff Modality. The final costs of the Energy Tariff (*Tarifa de Energia* – TE, or ET) and the Distribution System Use Tariff (*Tarifa de Uso do Sistema de Distribuição* – TUSD, or DSUT) are periodically reviewed and published by ANEEL for each utility. They are also determined by the time-of-use period, which for this study is considered as a set of 3 daily hours for peak hours and the hours complementary to peak hours, called off-peak hours (Schutze, 2015).

In addition to the tariffs, the Program of Incentives for Alternative Electricity Sources (*Programa de Incentivo às Fontes Alternativas de Energia Elétrica* – PROINFA), established by Law No. 10,438/2002, aims to increase electricity share by independent generators of renewable sources, such as solar, wind, Small Hydroelectric Plants, and biomass, in the National Interconnected System (*Sistema Interligado Nacional* – SIN). Thus, some of the tariffs applied to the FCE depend directly on the climatological scenario, likewise to the generation, transmission, and distribution conditions of the electricity at the analyzed timeframe. There are also charges that apply directly to this bill to support the security of the national electrical system. The System Service Charge (*Encargo de Serviço de Sistema* – ESS) and the Reserve Energy Charge (*Encardo de Energia de Reserva* – EER) are the main charges applied to the total energy cost, affecting both the RCE and the FCE. These charges influence the final price regarding variations in energy generation availability, as they are directly related to the effort to ensure the security, reliability, and stability of the national electrical system (Brazil, 2002; MME, 2024).

Costs linked to the final energy value are also determined by atypical moments such as a pandemic or unusual water shortages. Among these are the Energy Development Accounts (*Contas de Desenvolvimento Energético* – CDE) with the Covid Cost (CDE-COVID) and the Water Scarcity Cost (CDE-CEH). The CDE-COVID represented a financial operation to relieve the cash flow of energy distributors during the Covid-19 pandemic. The CDE-CEH was also a financial operation created to mitigate the tariff impacts of the severe water crisis in 2021, which required the exceptional dispatch of expensive thermal generation and energy imports (Brazil, 2020; ANEEL, 2022b).

However, losses that the system incurs throughout the transmission of electrical energy are also considered at the end. Determined as the Basic Grid Loss Factor, this technical index represents the adjustment of the energy volumes contracted in FCE, considering the technical energy losses that occur during the transportation of electricity by grid within the national transmission system, from generation to consumption point. In this paper, only the CDE-COVID was not considered, as the remaining tariffs and charges are still in effect for the region covered in this study (ANEEL, 2022c). With these definitions, consumption and cost values over time proceed to be arranged.

2.3 Modulation, Seasonality, and Flexibility

It is necessary to adjust the Consumer Unit profile according to how its energy consumption behaves throughout the year, which is called seasonality, with the energy consumption data series distributed over specified timeframe. This manner translates into higher consumption during certain hours of a day and lower consumption during others. Each typology of CU – such as hospitals, penitentiaries, administrative units, among others – represents a specific consumption profile, hourly demand, and specific needs. Over a 12-month period, it is possible to identify times of the year where demand versus cost is more advantageous or disadvantageous. To mitigate the impact of these variations on an energy contract, a margin for demand fluctuation and its corresponding charge is established. This allows, for example, the contractor not to be penalized for exceeding the contracted demand during peak periods or for having consumption far below expectations that it also exceeds a pre-established minimum in the contract. This tolerance band is called flexibility (EPE, 2020; ANEEL, 2021).

Seasonality can be implemented in two ways for an energy purchase notice: by considering the annual consumption variation of each CU, agreed upon between stakeholders – typically used in private initiatives; or the flat model, where the annual energy quantity, in average megawatts (MWm), is divided proportionally by the number of hours in the months throughout the year – common in notice promoted by the public sector. Together with seasonality, the modulation of energy values within a pre-determined period helps shape the prices agreed upon in a contract. It can be structured in a format that varies according to the months or be distributed uniformly, named flat modulation (Takigawa et al., 2021).

3. Methodology

This research is characterized as exploratory, both qualitative and quantitative in nature, using the case study method for the qualitative stages – which sought to identify the CUs with the highest consumption and highest concentration per National Registry of Legal Entities, known as CNPJ in Brazil, lacking their own energy generation solutions – and an analysis of the cost-effectiveness of the transition in the quantitative stage.

The analyses conducted in this work followed these methodological steps: (1) define concepts related to the FCE; (2) select the department with a volume of suitable demand, load profile for migration, and be a case study model; (3) gather a collection of consumption, demand, and other data aspects from the Consumer Units related to the chosen department; (4) apply parameters for selecting and filtering data of demand and energy costs; (5) project energy cost for the FCE based on consumption and demand data, current tariffs and charges, including other market values; and (6) build the case study and further analysis of results to stand for or against the migration of CUs to the FCE.

3.1 Case study

The migration feasibility of the selected units and the potential for cost savings on electric energy consumption was determined upon the environmental characteristics of established timeframe and the selected units' conditions. In this case, the Consumer Units were characterized by their electric energy consumption, selecting a data timeframe from 2024 and 2025, with all belonging to Group-A of medium voltage. Thus, the tariffs, charges, and other fees related to the period were surveyed and adopted in the migration evaluation.

Data on energy consumption during peak and off-peak hours were organized, as well as the monthly and total averages for each CU. The DSUT for peak and off-peak hours, and the ET for both blue and green modalities were also gathered for scenario evaluations for the units – referring to charges applied to those migrating to the FCE, such as the water scarcity charge, and finally, the tariff flags for each month surveyed.

Alongside the tariff charges, common to all CUs, individual values such as energy prices from traders were incorporated into this analysis, measuring the scale of influence of this variable compared to the common practiced in the RCE. The prices were distributed over 5 years, a period commonly observed in contracts of the same nature between traders and public initiative. Similarly, consumption and demand values, applicable discounts, taxes, and readjustment indices were considered.

It is noted that, in Table 2, the values for the loss factor and PROINFA quotas were nonetheless considered, despite having little influence on the feasibility analysis result for Public Sector facilities. Conversely, values related to taxes, such as ICMS (*Imposto sobre Circulação de Mercadorias e Prestação de Serviços* or Tax on Circulation of Goods and Services) and public lighting, are not applied in this analysis since the consumer units are exempt from these contributions (Brazil, 1988; Espírito Santo, 2002).

The values were organized in Table 2, which considered, for the analyzed period, values of the current demand tariffs, charges, tariff flags, loss factor, and quotas. These data were included for both contracting environments, respecting their particularities, since the study resides in the comparison between them.

Table 2: Tariffs, charges, and tariff flags considered in this work.

Wire-Use Tariffs – Regulated Contracting Environment (RCE)			
Blue Modality	**(USD/kW)**	**Green Modality**	**(USD/kW)**
DSUT Peak	7.86	DSUT (R$/kW)	5.96
DSUT Off-Peak	5.96	Charges Peak	246.67
Charges Peak	30.18	Charges Off-Peak	30.17
Charges Off-Peak	30.18		
Blue/Green Modality	**(USD/MWh)**	**Water Scarcity Quota**	**(USD/MWh)**
ET Peak	89.37	-	0.71
ET Off-Peak	56.02		
Tariff Flags			
Green Flag (USD/MWh)	No additional charge		
Yellow Flag (USD/MWh)	3.51		
Red Flag I (USD/MWh)	8.33		
Red Flag II (USD/MWh)	14.69		
Tariffs and Charges in the Free Contracting Environment (FCE)			
Loss fator	3.0%		
PROINFA Quotas	2.5%		

The energy cost values were obtained from the commercial prices disclosed by an energy supplier, CEMIG (*Companhia Energética de Minas Gerais*), for the initial period under analysis, as addressed in Table 3. Similarly, the number of months to be analyzed in the comparison between the RCE and FCE was determined for the projection of the values.

Table 3: Cost of energy in the ACL for the period analyzed, based on a commercial agent.

Year	**Cost (USD/MWh)**	**Number of months per year**
2026	60.31	7
2027	52.72	12
2028	49.47	12
2029	46.56	12
2030	44.88	12
2031	44.76	5

To exemplify the methodology adopted for the present work, a data sample was established to determine the potential for cost savings on electrical energy consumption. This sample keeps the characteristics discussed in the previous subchapter, applied to the electrical energy consumption data of the state government's CUs. This resulted in an initial sample restricted to one of the government's departments – the Department of Justice (DoJ). Consequently, the characteristics of the CUs, particularly the consumption and demand of each one, were processed to compose the global cost estimate for the feasibility analysis.

3.2 Consumer Units

The Consumer Units were selected based on the premise that their electrical energy consumption is funded by the Public Sector, specifically by the State Government. From this subset, the total number of public facilities connected to the state was surveyed, and from this total, 32 units belonging to the DoJ were chosen as they possessed the load and consumption profile suitable for migrating to FCE. For the most part, the selected CUs exhibit high energy consumption during off-peak hours, which translates to a high electricity cost for the state.

Besides the high-consumption profile, the CUs were categorized under the green tariff modality, representing a fiscal advantage since the DSUT in this modality is simplified regarding contracted demand, resulting in a lower cost compared to the blue modality. Coupled with this fact, the total amount of energy generates attractiveness for energy traders, which should be considered for the bidding process to hire a representative agent at the CCEE.

3.3 Averages and Feasibility Analysis Estimates

With all the values for active electrical energy consumption, during both peak and off-peak hours, and taking into account the adoption of green energy — according to current regulations, with a 50% discount to compose the electricity cost in the FCE — along with tax exemptions and without adjusted tariffs (as they are Public Sector CUs), the average consumption of all selected CUs can then be determined. Knowing that the total cost for each contracting environment was considered as treated in Equations 1 and 2, the costs related to each of them can be estimated.

$$RCE = DSUT + \mathrm{ET} \qquad \text{(Eq. 1) e}$$

$$FCE = DSUT + Cost_{FCE} \qquad \text{(Eq. 2)}$$

The costs were considered according to each tariff modality to estimate the cost for each of the CUs involved in this study. The DSUT for the Green Modality was calculated according to the variables present in Equation 3:

$$DSUT = (D_c * DSUT_{wire}) + \left(C_p * DSUT_p\right) + \left(C_{off} * DSUT_{off}\right) \qquad \text{(Eq. 3)}$$

The formula considers the Contracted Demand (Dc) by the CU in kW; the Distribution System Use Tariff for wire usage (DSUTwire) in USD/kW; the monthly energy consumption during peak hours (Cp) in MWh; the monthly energy consumption during off-peak hours (Coff) in MWh; the Distribution System Use Tariff for energy charges during peak hours (DSUTp); and finally, the Distribution System Use Tariff for energy charges during off-peak hours (DSUToff), both of the latter in USD/kW.

Subsequently, for the Distribution System Use Tariff in the Blue Modality, the variables present in Equation 4 were considered:

$$DSUT = \left(D_p * DSUT_{wp}\right) + \left(D_{off} * DSUT_{woff}\right) + \left(C_p * DSUT_p\right) + \left(C_{off} * DSUT_{off}\right) \quad \text{(Eq. 4)}$$

This includes the Contracted Demand by the CU during peak hours (Dp) in kW; the Contracted Demand during off-peak hours (Doff) in kW; the Distribution System Use Tariff for wire usage during peak hours (DSUTwp) in USD/kW and during off-peak hours (DSUTwoff) in USD/kW; the monthly energy consumption during peak hours (Cp) in MWh; the monthly energy consumption during off-peak hours (Coff) in MWh; the Distribution System Use Tariff for energy charges during peak hours (DSUTp); and finally, the Distribution System Use Tariff for energy charges during off-peak hours (DSUToff), both also in R$/kW.

Alongside the DSUTs, the ET was calculated considering the following variables, listed in Equation 5, which are the consumption by CU during peak hours (Cp); the Energy Tariff during peak hours (ETp); the consumption by CU during off-peak hours (Coff); and the Energy Tariff during off-peak hours (EToff).

$$ET = \left(C_p * ET_p\right) + \left(C_{off} * ET_{off}\right) \qquad \text{(Eq.5)}$$

Finally, the discounts relating to each of the tariff modalities (DSUTd) are included, as organized in Equation 6 for the blue modality and Equation 7 for the green modality.

$$DSUT_d = \text{DSUT} - 0{,}5 * \left[\left(D_p * DSUT_{wp}\right) + \left(D_{off} * DSUT_{woff}\right)\right] \qquad \text{(Eq. 6)}$$

$$DSUT_d = \text{DSUT} - 0{,}5 * \left(D_c * DSUT_w\right) + C_p * 0{,}5 * \left(DSUT_p - DSUT_{off}\right) \qquad \text{(Eq. 7)}$$

In this manner, by comparing Equations 1 and 2 results, the cost for each of the scenarios pertaining to the CUs in both the RCE and the FCE was determined.

4. Results and discussion

The results were established based on the final values derived from the peak and off-peak energy of selected consumer units' consumption. These values, along with tariffs were applied to the Regulated Contracting Environment and the Free Contracting Environment for selected months in 2024 and 2025 (ANEEL, 2025; CCEE and ANEEL, 2024), as well as any applicable tariff flags within the defined timeframe (EDP Brasil, 2024). Consequently, the consumption and demand values of the state-related CUs were aggregated, in addition to the tariff modality and calculated total consumption, representing the annual acquisition volume for the 32 Consumer Units, in average megawatts, as shown in Table 4.

Table 4: Relation of the total consumption of the selected Consumer Units for the feasibility analysis.

Annual Peak Consumption (MWh)	974.71	**Tariff Modality**	Green A4
Annual Off-Peak Consumption (MWh)	9,970.30	**Annual Peak Demand (kW)**	30 a 150
Total Annual Consumption (MWh)	10,945,01	**Annual Off-Peak Demand (kW)**	30 a 300
Total Annual Consumption (Average MW)	1.25		

By correlating the total average annual consumption with the values from Table 3, the results were observed in Table 5, with the goal of migration analysis completed. These highlight the significance of reducing electricity costs for these units when consumption data is compared, showing an increase in order of 10 times of peak consumption value, and a double fold in scale of annual demand between peak and off-peak time slots, moving from 30-150 kW to 30-300 kW (Table 4). These changes occur during a more costly time, resulting in a higher electricity consumption cost for the state.

Regarding these increasing proportions, the feasibility of migrating CUs selected to the FCE becomes clearer when scenarios for both contracting environments are quantified and organized in terms of costs, as indicated in Table 5. As observed, in the most unfavorable scenario, such as the regulated market cost scenario under a Red Flag, Level 2 tariff, the economic advantage exceeds 30%, creating real savings of over 2,4 million dollars for public coffer. Even when compared under a favorable scenario, the cost reduction remains around 22.24%, leading to a cut of more than 1,4 million dollars over a 5-year horizon.

Table 5: Comparison of costs between the Regulated Contracting Environment and the Free Contracting Environment.

Scenario	Total Amount (USD)	Savings (USD)	Savings (%)
Consumer Units	CU 1 to 32		
Cost in FCE	5,520,888.23	-	
Cost in RCE – Green Flag	7,100,223.94	1,579,450.09	22.24%
Cost in RCE – Yellow Flag	7,302,770.29	1,782,359.78	24.40%
Cost in RCE – Red Flag I	7,580,244.20	2,059,867.03	27.17%
Cost in RCE – Red Flag II	7,947,698.01	2,427,365.00	30.54%

Thus, the feasibility analysis for migrating the selected Consumer Units from the DoJ to the Free Contracting Environment proved favorable, with the potential for positive returns in both the technical aspects of the transition process—whereby the professional expertise of the involved actors is enriched—and the economic aspects, as suggested in this study.

5. Conclusion

The challenges in determining whether Consumer Units are suitable to migrate from a consolidated and predictable environment such as the Regulated Contracting Environment to the Free Contracting Environment require a significant amount of data and extensive analyses that contain sufficient quality to support large-scale decisions, ensuring a certain degree of predictability. The public authority requires that services provided to it be of a high degree of reliability and excellence, since it will be a service remunerated with public resources for the benefit of the population.

On this scenario, it is noted that the Government of the State of Espírito Santo established the Sustainable Energy Management Laboratory through an agreement via a research support foundation (*Fundação de Amparo à Pesquisa e Inovação do Espírito Santo* – FAPES). This agreement was signed by the Department of Management and Human Resources with the Arandu Institute of Sustainable Management and Development. The laboratory is under the coordination of the Department of Science and Technology researchers, and with the laboratory creation, it implemented a series of measurements such as research, extension, and technological development actions, focused on mainstream sustainable solutions directed toward the migration of the state's electric energy matrix. Among the actions in progress, the following stand out: the diagnosis and development of the Energy Management and Analysis Plan for energy transition of state buildings; the development of a Performance Monitoring System for Mini and Micro-generation Systems; the analysis of photovoltaic energy generation systems existing in state buildings; the modeling of Net Zero Energy Buildings (nZEB) and Virtual Power Plant (VPP) for state buildings; the development and implementation of contracting for the lease of photovoltaic assets for low-voltage consumer units; the study for tariff revision of medium-voltage consumer units; the implementation of the state's own mini power plant as a strategy to serve as a control group for comparison with other solutions; and, finally, the feasibility analysis and implementation of contracting sustainable energy on FCE for medium-voltage consumer units.

At the beginning of this work, the analysis focused on only one of the state government's departments, initially resulting in 32 Consumer Units, then reduced to 29 units after excluding facilities with under voltage requirements. During the development process of the migration feasibility studies, meetings between the research team and stakeholders directly involved in the project included more secretariats and, consequently, more CUs. This move represented the intention to increase the attractiveness of the project call with over 60 Consumer Units, totaling over 5 MW average throughout a year, thereby increasing both potential for reduced energy consumption costs and the project's complexity.

Therefore, with economic aspects corroborating the advantage of changing between markets, it remains a valid option, even at larger scales of change and investment, as well as in capacity for building and transformation toward an agenda guided by sustainability. This migration process can be implemented by adopting practices already consolidated in the Free Contracting Environment, even if not widely known, particularly regarding the execution method applied to scenarios in the public sector. There is a need for investment in means to facilitate data acquisition, such as APIs, and for recurrent, precise, unbiased, and complete information from the companies involved in this market, to facilitate projections and feasibility studies. Furthermore, the maturation of the Free Contracting Environment in Brazil places it in an exploratory context with potential positive developments for society, as it will directly benefit from financial savings and sustainability through the consumption of clean energy.

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