Research, Society and Development, v. 11, n. 6, e2211628673, 2022
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v11i6.28673

Business model and feasibility analysis for energy production as a self-producer by lease

Modelo de negócio e análise de viabilidade para produção de energia como autoprodutor por locação

Modelo de negocio y análisis de factibilidad para la producción de energía como un autoproductor de arrendamiento

Received: 03/30/2022 | Reviewed: 04/07/2022 | Accept: 04/13/2022 | Published: 04/18/2022

Fernanda Souza Vianna
ORCID: https://orcid.org/0000-0002-8131-1278
Universidade Federal Fluminense, Brazil
E-mail: fernandavianna@id.uff.br
Kátia Silene de Oliveira Maia
ORCID: https://orcid.org/0000-0002-7730-6708
Universidade Federal Fluminense, Brazil
E-mail: ksdom@uol.com.br
Paulo Roberto Monteiro Duailibe
ORCID: https://orcid.org/0000-0002-7376-9115
Universidade Federal Fluminense, Brazil
E-mail: pauloduailibe@id.uff.br
Dick Farney Pimentel Rocha
ORCID: https://orcid.org/0000-0003-2651-4301
Dick Idiomas, Brazil
E-mail: complexitate@gmail.com

Abstract
The Electric Sector in Brazil is currently based on the presence of two markets for contracting energy. One available for access to all consumers only in the concession format, with contractual freedom and exclusive access by the government contracted for media consumption. These are respectively the Regulated Contracting Environment (ACR) and the Free Contracting Environment (ACL). In this last agent, among the other energy generators, the self-producer agent is defined, which has the right to generate energy for its own consumption. This configuration opens possibilities for media consumers, if the project is not regulated by a project that is not compatible with the market. Being a promising model, but recent in the market, it is necessary to define its general aspects, such as the aptitudes and costs of the enterprise, as well as to validate the economic viability of the model and its potential to reduce electricity costs. For this, applied research and a study of the Fluminense case will be presented, based on the values of the Federal University from a base and comparing them with market values for the new model. This article briefly presents aspects of the structuring of the Brazilian electricity sector, as well as the characteristics and differences of each contractual environment, such as the instruments of each market and its commercialization rules, in addition to the business model of self-production of energy of photovoltaic origin by asset leasing developed for Universidade Federal Fluminense to reduce electricity costs.
Keywords: Self-producer; Free energy market; Photovoltaic Plant; Feasibility analysis; Retail trader.

Resumo
O Setor Elétrico no Brasil está atualmente baseado na presença de dois mercados para contratação de energia. Um disponível para todos os consumidores no formato de concessão regido pelo governo e outro, competitivo, com liberdade contratual e acesso apenas para consumidores de média tensão, com demanda contratada. Estes são respectivamente o Ambiente de Contratação Regulada (ACR) e o Ambiente de Contratação Livre (ACL). Neste último, dentre os demais agentes geradores de energia, define-se o agente autoprodutor, que detém o direito de gerar energia para consumo próprio. Esta configuração abre possibilidades para consumidores em média tensão, se tornando um projeto com vantagens econômicas que não são obtidas no mercado regulado. Sendo um modelo promissor, porém recente no mercado, é necessário definir seus aspectos gerais, como quais consumidores estão aptos e custos do empreendimento, bem como validar a viabilidade econômica do modelo e seu potencial na redução de custos com energia elétrica. Para isso, serão apresentados uma pesquisa aplicada e um estudo de caso, tomando como base a Universidade Federal Fluminense, utilizando os valores gastos com energia a partir de um ano base e comparando-os com valores de mercado definidos para o novo modelo. Este artigo apresenta de forma sucinta aspectos da estruturação

do setor elétrico brasileiro, bem como as características e diferenças de cada ambiente contratual, como os instrumentos de cada mercado e suas regras de comercialização, além do modelo de negócio de autoprodução de energia de origem fotovoltaica por locação de ativos desenvolvido para Universidade Federal Fluminense para redução de despesas com energia elétrica.
Palavras-chave: Autoprodutor; Mercado livre de energia; Usina Fotovoltaica; Análise de Viabilidade; Comercializadora varejista.

Resumen
El Sector Eléctrico en Brasil se basa actualmente en la presencia de dos mercados para la contratación de energía. Uno disponible para todos los consumidores en el formato de concesión regido por el gobierno y el otro, competitivo, con libertad contractual y acceso solo a consumidores de media tensión, con demanda contratada. Estos son respectivamente el Ambiente de Contratación Regulada (ACR) y el Ambiente de Contratación Libre (ACL). En este último, entre los demás agentes generadores de energía, se define el agente autoproductor, que tiene derecho a generar energía para su propio consumo. Esta configuración abre posibilidades para los consumidores de media tensión, convirtiéndolo en un proyecto con ventajas económicas que no se obtienen en el mercado regulado. Al ser un modelo prometedor, pero reciente en el mercado, es necesario definir sus aspectos generales, como qué consumidores son capaces y los costos del emprendimiento, así como validar la viabilidad económica del modelo y su potencial para reducir los costos de energía eléctrica. Para ello, se presentará una investigación aplicada y un estudio de caso, con base en la Universidade Federal Fluminense, utilizando los valores gastados en energía de un año base y comparándolos con los valores de mercado definidos para el nuevo modelo. Este artículo presenta brevemente aspectos de la estructuración del sector eléctrico brasileño, así como las características y diferencias de cada entorno contractual, como los instrumentos de cada mercado y sus reglas de comercialización, además del modelo de negocio de autoproducción de energía. de origen fotovoltaico por arrendamiento de activos desarrollado para la Universidade Federal Fluminense para reducir los costos de energía eléctrica.
Palabras clave: Autoproductor; Mercado de energía libre; Planta Fotovoltaica; Análisis de viabilidad; Comerciante minorista.

1. Introduction

It is possible to infer that the cost of electricity in Brazil has increased over the years, with increasing fares, especially for regions that make up the Southeast/Midwest submarket and consumers that are characterized between the residential and public power classes. (Acende Brasil Institute, 2022). In view of this increase in energy costs and the constant dependence on this input, it is increasingly necessary to enable the use of energy in an efficient and economical way and to propose business models capable of solving these difficulties. For low voltage consumers there is the possibility of generating energy through micro and mini distributed generation models. (CCEE, 2021a; CCEE, 2021b). However, these known and widespread alternatives do not include consumers who need an installed power greater than 5MW for their generation. The alternative, then, comes through the possibility of producing energy, outside the so-called regulated market, in the Free Energy Contracting Environment. This environment has been growing more and more over the years, since its implementation, after the reforms that took place in the Brazilian electricity sector dating back to the beginning of the 21st century.

The main objective of this article is to present a new model of energy production, in the form of self-production, by leasing assets to the Universidade Federal Fluminense (UFF). An economic feasibility study was developed, being formulated through an analysis of electricity expenses in the regulated market, in comparison with the energy cost in the studied model. Additionally, the general aspects of the self-production model by leasing of assets are presented, as well as the characteristics of the Free Energy Market.

2. Methodology

It is applied research and a case study with a quantitative approach. The research universe is the Universidade Federal Fluminense (UFF) based in the city of Niterói - RJ. The other campuses are located in this city and in eight other municipalities in the interior of the State of Rio de Janeiro. (International, 2021). A total of 63 consumer units (UCs) were considered as the basis of the case study, divided between 38 medium voltage (MT) units and 25 low voltage (LV) units. These UCs are divided

among four distributors, depending on the concession area in which the unit is served.

According to Clement Jr (2012), the study of case's method of study is an empirical investigation that investigates a contemporary phenomenon in its real life's context, even if the limits between the study's phenomenon and its context are not clearly defined. The cases for the study, also called the method's case, they are reconstructions of problematic management or organizational situations to didactic purposes. A different research strategy that allows the researcher to build up his own ways and adjust his project in the search of the proposed objectives.

A discussion about the business model will be presented with a historical bias of the sector, applied research along with the case study and finally the conclusions on the subject.

In the first part, a literary review and rationale of the business model will be presented, in order to outline the themes related to the object of study, ensuring the reader's understanding of the concept of energy self-production. In addition, the bibliometric research carried out on the subject is described, as well as the evolution of the Brazilian electricity sector, focusing on the current context. In the second section will be exposed the base data of expenses and consumption of the University, the motivations for the study of a new model of energy generation, as well as the description of the equation thought for the comparison of costs between scenarios. UFF's expenses with energy will be evaluated in relation to a base year and these values will be compared with the price in the new energy contracting model based on commercial proposals received by the University. Finally, in the last part of the article, conclusions regarding the topics discussed and the results obtained will be presented.

3. Discussion

3.1 Free Market

The electrical system has two energy contracting environments, the aforementioned ACR and ACL, the second being commonly called the Brazilian free energy market. This model, with the presence of two different environments, was implemented in the year of execution of the sector, after the sector implementation crisis in 2001. (CCEE, 2021c; CCEE 2021d).

In the first environment, we have the purchase and sale of energy regulated by ANEEL, with prices established at auction and pre-defined fares. Consumers, said to be captives, are supplied with energy through distribution concessionaires in the region in which they are located and are restricted to this structure, without permission to purchase energy through the free market. In the second environment, created with the aim of stimulating the sector's competitiveness, consumers have the possibility to buy energy from companies associated with the market, without a direct relationship with the energy concessionaires. In this way, they can negotiate all aspects of the contract, from resource price, type and duration of contract and other services such as energy management reports.

The management of both environments is the responsibility of the Câmara de Comercialização de Energia Elétrica (CCEE), an institution that, among other functions, records all contracts signed in both environments. To integrate the electricity sector, agents need to be associated with CCEE.

3.2 Participating Agents

Among the agents associated with CCEE that participate in the free market are generators and traders. Generating agents are those that can sell energy and are divided into three classes, Public Generation Service Concessionaire, Independent Electricity Producer and Self-producer.

This last class is defined by agents with concession, permission or authorization to produce energy for their exclusive use. They also have the exemption of sector charges and the reduction of fares for the use of electrical transmission and distribution systems (TUST and TUSD), which can reach up to 50% discount. (ANEEL, 2004; ANEEL, 2016). Self-production can be remote or in the same place where consumption takes place. Furthermore, it is not restricted to the concession area, only

to the submarket in which the plant is located. (ANEEL,2012; Grid Energia, 2021). If there is a surplus of energy, you can sell it with an authorization granted by ANEEL. (CCEE, 2021e).

The category of trading agents is formed by importing, exporting and trading agents of electricity, in addition to free consumers and special consumers. In the ACL, through bilateral contracts, traders buy energy and can resell this energy to free consumers or to other trading companies. (CCEE, 2021f).

3.3 Consumers in the ACL

There are two classifications for consumers who migrate to the ACL, the conventional free consumer and the special consumer. To become a conventional free consumer, it is necessary to be a consumer unit that has a minimum contracted demand of 1,000 kW, as established in a government ordinance for the year 2022 (Governo, 2019). Once this requirement is met, these agents can contract conventional energy, from hydroelectric plants or gas-fired thermal plants, or special energy, from renewable energy sources, such as biomass, wind, PCH or solar. On the other hand, the special consumer can only enter into a contract with energy from renewable sources. In addition, it can be characterized by a unit or set of consumer units that are presented in the same location and under the same CNPJ, with a minimum load of 500 kW, considering the total of contracted demands. (ABRACEEL, 2021).

3.4 Business Model: Self-production by Lease

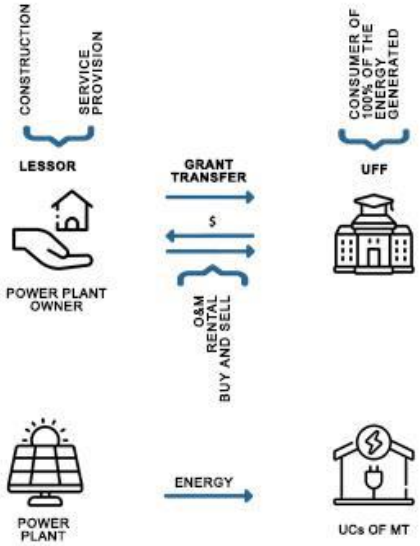
The leasing model for a self-producing agent has the characteristic of being an enterprise built specifically with the objective of guaranteeing the energy consumption of the consumer, similar to the built to suit[1] real estate leasing model. The model proposed for Universidade Federal Fluminense would then be the location of an entire self-production system, including the photovoltaic generating plant and its equipment, the land and the maintenance and operation services.

The formalization of the model must be through public contracting, since the UFF, being a Federal Institution, is under the Public Bidding Law (Law 8.666/93). Therefore, the contract would be concluded through a bidding process, for which the open mode [2]was defined by the criterion of lowest global price, that is, the total lease value for a period of 15 years. In this model, the CAPEX (capital expenditure) of the generation asset belongs to the investor/lessee and is granted on behalf of the consumer/lessor. Likewise, the operation and maintenance services would also be under the responsibility of the contracted company. The figure 1 describes the model:

[1] Property leasing model where the CAPEX of the construction or renovation belongs to the lessor with specifications defined by the lessee. Contractor pays the lease amount added to the amount invested in the property and the investment is diluted in the monthly payments. The property can only be repossessed at the end of the contract. (Brasil, 2012)

[2] In the open mode, bidders submit successive public and successive bids, with extensions, based on the judgment criteria adopted in the public notice. (Governo, 2021)

Figure 1. Business Model for Self-production by Lease.



Source: Adapted by the author of the commercial proposal.

In addition to the investor, it would be necessary to hire an energy trader, responsible for the sale of surpluses and for the operations in the Electric Energy Commercialization Chamber. All these services could be contracted separately or included in the lease itself, according to Figure 2:

Figure 2. Proposal assumptions.

Proposal

Asset leasing (equipment + land)
Provision of O&M services at the Plant
Provision of retail marketing services

Grant holders: UFF.

Regime: Self-producer of Electric Energy.

Energy destination: UFF medium voltage UC.

Need for energy commercialization contract: Yes, for the purposes of registration with the CCEE and commercialization of surplus energy.

Exemption from sector charges: CCC-Isol, PROINFA and CDE: Yes.

Discount on TUST/TUSD: Yes (at least 50%)

Source: Adapted by the author of the commercial proposal.

In the free energy market, there are two types of traders, traditional and retail. By choosing to migrate to the ACL under a retail trader, the consumer makes the trader agent responsible for the entire intermediary with the CCEE (Almeida, 2018). In this case, UFF, in the role of consumer, does not need to be associated with CCEE, since the relationship will always be one-to-one, between the consumer and the retailer and between the retailer and the CCEE. This classification of retail agent aims to facilitate the entry of new consumers into the free energy market, as it eliminates bureaucracy. (Pereira, 2019). It is also your responsibility to support the contractor in scenarios related to energy management. Some examples of these are advising on the process of migration from UCs to ACL, both legal and practical, promoting a Monthly Energy Balance and carrying out the

constant analysis of the contract with the distributor, due to occasional variation of TUSD. (UFF, 2021a).

3.5 Current Context

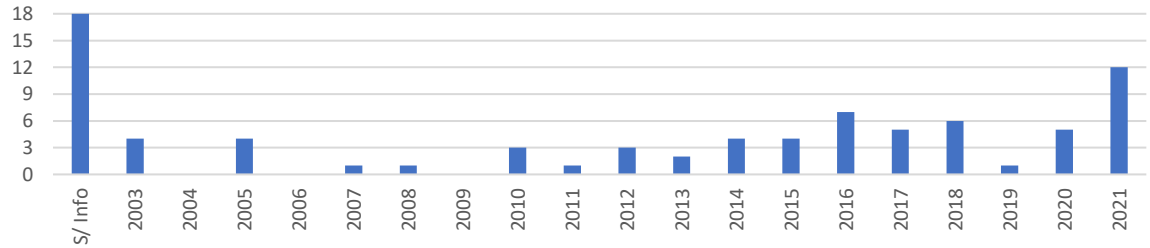
In order to validate the current relevance of the concept of self-production in the energy market, a bibliometric research was carried out on the subject addressed. This was performed in the Web of Science database using the following filter "Photovoltaic (All Fields) AND free energy market (All Fields)" with the additional filter of region such as Brazil, directing the analysis to results that directly relate power plant projects photovoltaics with the free market. The terms "self-producer" and "self-production" were excluded, as well as their translations into English since the results obtained with these words had no correlation with the topic of electricity production. Only four works were found, three of which were recently published. (Web of Science, 2021).

The fact of finding few results directed to the production of energy in the free market, shows that there is little literature already produced related to the subject, therefore there is a great potential for the development of new studies. The increase in the discussion on the subject is possible, since the participation of the free energy market has been gaining strength, especially after the context of the coronavirus health crisis.

According to the CCEE study, between 2019 and 2020, the free market showed a 2.8% increase in consumption, associated with an increase of 5239 consumer units and the addition of 1522 agents. The regulated market closed the period with a drop of 3.4%. (CCEE, 2021a). Similarly, in the first month of 2021, the country's consumption followed the same trend, with an increase of 10.7% in the ACL and a decrease of 0.5% in the ACR. (CCEE, 2021g).

In July 2020, the Electric Energy Commercialization Chamber had more than 10 thousand agents. (CCEE, 2021h). Among the associated agents, less than 1% were self-producers. This number is not expressive, however, when following the historical evolution of the class it is possible to perceive a growing, even if inconstant form. In a survey carried out at the end of 2021, the agents classified as self-producers associated with CCEE totaled 81 companies. (CCEE, 2021i), according to figure 3:

Figure 3. Historical series of the "self-producer" class.



Source: Own elaboration based on CCEE data (2021i).

4. Results

4.1 Definition of Base Data

The analyzed database includes the values of energy consumption and expenses related to UFF's 2019 invoices. This information was made available by the Universidade Federal Fluminense, through the energy sector belonging to SOMA (Superintendence of Operations and Maintenance). Data for 2020 and 2021 were disregarded as they did not portray the reality of energy consumption at the University due to the Coronavirus pandemic, as UFF adopted the remote teaching system and restricted access to its facilities.

In order to adapt to the self-producing model by asset leasing, the focus of the study should be on medium voltage units. This is because the greatest economic gain with migration will be obtained in these units, as they consume the most energy. In

addition, in these CUs there is a difference in pricing by modality, which considers contracting on demand and the use of energy in peak (P) and off-peak (FP) time bands, which can cause poor resource management and high costs.

In the UFF's budget, energy costs have always been of great importance. In 2019, the total cost of energy at UFF was R$ 20,097,434.18, adding up the billings of consumption, in medium and low voltage, contracted demand, exceeded and surplus reactive, not including the amounts of taxes, duties, fines, interest and other charges. Of this total amount, 99% refer to medium voltage units.

The consumption data of the 38 medium voltage units were analyzed over a period of 12 months. The base year consumption in these UCs reaches approximately 18 GWh/year, according to table 1:

Table 1. Consumption and billed amount in UFF Total Voltage per month (2019).

Mês	kWh P	kWh FP	kWh Total	Amount P. (R$)	Amount FP(R$)	Amount (R$)
jan	128.129	1.269.638	1.397.767	397.125,13	705.646,14	1.102.771,27
fev	125.304	1.405.953	1.531.257	393.761,79	793.872,32	1.187.634,11
mar	109.613	1.215.039	1.324.652	327.133,93	657.443,37	984.577,30
abr	194.601	1.553.205	1.747.806	564.586,21	891.610,71	1.456.196,92
mai	174.102	1.506.048	1.680.150	535.182,38	887.283,71	1.422.466,09
jun	176.073	1.390.532	1.566.605	538.917,60	821.120,74	1.360.038,34
jul	145.598	1.181.457	1.327.055	444.992,16	688.306,93	1.133.299,09
ago	108.841	1.006.564	1.115.405	341.154,01	623.013,92	964.167,93
set	139.282	1.103.734	1.243.016	436.786,21	717.443,51	1.154.229,72
out	170.817	1.310.204	1.481.021	543.407,48	831.718,07	1.375.125,55
nov	194.707	1.591.147	1.785.854	589.762,96	956.962,10	1.546.725,06
dez	163.612	1.398.198	1.561.810	502.174,06	871.624,65	1.373.798,71
TOTAL	1.830.679	15.931.719	17.762.398	5.614.983,92	9.446.046,17	15.061.030,09

Source: Adapted by the author of Monteiro et al. (2021).

For these medium voltage units, two fare modalities applied by contract were observed, THS Verde[3] in the A4 subgroup[4], in which the vast majority of UCs have their contract signed, and Optante Dem CI A4, for only two UCs of UFF.

For the first case, it is important to emphasize that there is a great possibility of savings, not only through a migration to self-producer, since many units have the wrong contracted demand. There are units where the University pays a higher price for the use of excess demand, which is naturally more expensive. As there are units where the monthly consumption is far below the contracted value, configuring an unnecessary expenditure of money, since the invoiced value, in these situations, corresponds to the contracted demand. (ANEEL, 2010, p131).

In the case of units that chose to be billed as the corresponding group B[5], the problem lies in the fact that the fare for group B becomes more expensive than the THS. In this type of contract, the same fare value is applied both during peak and off-peak hours. (Monteiro et al., 2021).

4.2 Equational Basis for Result Analysis

After defining the base data, the comparative method was applied based on the differences between expenses with electricity in the regulated market and self-production, the latter being based on 2 market proposals received in 2021. For the

3 THS Verde presents different energy consumption fares according to time slots and a single fare for power. (Pereira, 2019)
4 These are consumer units with a supply voltage equal to or greater than 2.3 kV, or with underground secondary voltage service. It presents subgroups divided by voltage range, with the A4 being customers with voltage between 2.3 and 25 kV. (Pereira, 2019)
5 Group B includes consumer units with a supply voltage of less than 2.3 kV. (Pereira, 2019)

regulated market, the amount spent by UFF was used in 2019, considering only the impact of consumption in kWh on the conventional bill of its consumer units. As for self-production in the free market, in addition to the scenarios obtained from the proposals, an average market price was defined, used as a benchmark for the business model.

Both proposals presented a final value for the energy to be contracted, based on expenditures related to consumption in kWh and a cost of using the distribution system associated with the submarket in which the plant would be allocated. In addition to the final value, the expected monthly discount, the savings in one year and the discount projection for the duration of the contract were also defined.

Both the average consumption applied and the value of using the system were calculated differently for each case, following the guidelines of each company. Therefore, to ensure the correct analysis of the results and the possibility of comparing them, it was necessary to bring all the values to the same base.

First, the amount spent in 2019 by UFF in the regulated market was defined. Adding the monthly bill associated with consumption in kWh for peak and off-peak periods, we obtained the total amount paid this year (F_{year}) and, based on an arithmetic average, the amount spent on energy per month (F_{month}). These values are reported in the table 2.

Table 2. UFF consumption-related spending data in 2019.

Billed Tip (R$)	Billed Off the Tip (R$)	Total Billed in the Year (R$)	Average kWh cost (R$)
5.614.983,92	9.446.046,17	15.061.030,09	1.255.085,84

Source: Own elaboration.

In the same way, the average monthly consumption in kWh of the University (C_{med}) was calculated. The interference of time slots was disregarded, following the methodology applied by the companies in their proposals, thus overestimating the average consumption of the UFF. These values are reported in the table 3.

Table 3. Data for obtaining the average monthly consumption of UFF.

kWh P	kWh FP	kWh Total in the year	kWh average per month
1.830.679	15.931.719	17.762.398	1.480.200

Source: Own elaboration.

Once the monthly consumption was defined, it was necessary to guarantee the use of the fares for use of the distribution network informed by the companies, which would be added to the value of energy generated in self-production. In both commercial proposals, reductions in sectoral charges were negotiated, such as: CDE and Proinfa, TUSD, TUST, EER, ESS-SE account on the self-produced portion. Therefore, the TUSD APE value presented in each commercial proposal was used, as they already consider the discounts assumed previously.

With the consumption and pricing parameters, it was then possible to obtain the corrected costs for the two bidders, using the following formulas:

$$V_{month} = C_{med} \times T \quad (1)$$

Where:

V_{month} the amount spent on energy in self-production to be billed per month in R$;

C_{med} the average monthly consumption of the UFF in kWh;

T is the total energy fare in R$/kWh.

$$T = (TUSD\ APE + CT_E)/1000 \quad (2)$$

Where:

T the total energy fare cost in R$/kWh;

TUSD APE the value of using the distribution system for self-producers in R$/MWh;

CT_E the value of the energy generated in R$/MWh.

For company A, there was still a need to summarize the total fare cost of energy T to be applied in equation (1), since the values were described for each concessionaire affected by the use of the system. An arithmetic mean was then made, considering the TUSD APE for each distributor applied in equation (2).

After obtaining the variable (V_{month}) for each of the proposing companies, the average contracting value was calculated by applying a weighted average, thus defining the market average scenario:

$$V_{monthC} = {(V_{monthA} + V_{monthB})}/{2} \quad (3)$$

Where:

V_{monthC} the average market value spent on energy to be billed per month in R$;

V_{monthA} the amount spent on energy to be billed per month for company A in R$;

V_{monthB} the amount spent on energy to be billed per month for company B in R$.

With the three amounts spent on energy per month, the amounts spent on energy per year were reached at for each case. Then, the amounts spent on energy in self-production, monthly and annually, were reduced from the corresponding amounts paid by UFF to distributors in 2019. From this operation, savings data were obtained for the two-time indexes for each of the three scenarios, in addition to the percentage discounts of these differences.

$$VPL = \sum_{t=0}^{n} \frac{F_C}{(1+i)^t} - I_0 \quad (4)$$

Where:

VLP the net present value discounted at rate *i*;

t the period in question, in unit of time;

n the number of periods of the flow;

F_C a generic flow for t = [0...n] which can be inputs or outputs;

i the discount rate;

I_0 the initial investment.

4.3 Considerations for each Scenario

In addition to the difference already mentioned in the base calculation of the amount paid for using the system in each of the proposals, some general characteristics of the enterprise were also different between companies. The table below shows these general aspects in a comparative way, in addition to considering the ideal scenario defined based on the market average.

Table 4. Data for obtaining the average monthly consumption of UFF.

	Scenario A	**Scenario B**	**Scenario C**
Power Plant Location	UFF Land – RJ	Distrito Federal	UFF Land - RJ
Installed Power	9.184 kWp	9.6 MWp	10MWp
Power Generation	17.700MWh/year	1,48GWh/mês	18GWh/year
Investments + O&M	Included	Included	Included
Adaptation Costs	Paid by the bidder	Pagos pela Universidade	Paid by the bidder
Contract Time	180 months (15 years) can be extended by 10 years	25 years	180 months (15 years) can be extended by 10 years
Rental Fee	667,9 R$/MWh	573,70 R$/MWh	-

Source: Own elaboration.

The location suggested in scenarios A and C for the construction of the plant refers to Area 1 of Figure 4, which is a land belonging to UFF, divided between the municipalities of Iguaba Grande and São Pedro d'Aldeia. For company B, the plant would be located on land in the Federal District, something that is not an impediment since it is only necessary for the plant to be located in the same submarket where the consumer units are located. It is worth mentioning that a great advantage of having the plant built on its own land is that the location can be used for the technological development of the University itself, becoming a research center.

Figure 4. Iguaba Grande Nucleus.

Source: UFF (2021b).

The cost of energy generated in the lease model at company A would be 400 R$/MWh. The value of the TUSD APE was presented, already with discounts, for each of the concessionaires that serve the medium voltage units at UFF. For Energisa the value of using the distribution system would be R$212.06/MWh, for Enel R$345.86/MWh and for Light R$245.79/MWh. Being obtained from equation (2), the value of energy in the lease would then be R$ 667.9/MWh. In commercial proposal B, the index composed of the cost of energy added to the fare for using the network for the APE was presented directly in the amount of R$ 573.70/MWh, not being necessary to equate it. Finally, in scenario C it is non-existent, since the final value is obtained through the average of the other two scenarios.

For all scenarios, both the investment and maintenance of the plant during the contract period would be borne by the partner company. The cost of adapting the CUs, on the other hand, was agreed differently in the two proposals. While company A assumes these costs, for company B, UFF would be responsible for the investment to replace the meters of the medium voltage

units. The total amount would be around R$20,000.00 per unit migrated. Considering the 38 units, this value was included in the long-term economic analysis, as the portion referring to the initial investment (I_0) of the VLP calculation. Finally, for scenario C, it was defined as an essential point that both the process of adapting the UCs to be served and their costs would be included in the proposal. Other considerations for calculating VLP were:

- The discount rate applied will be 10% per year, considering the rate defined in one of the proposals presented;
- No rate projection was made for the following years, nor was the lease agreement readjustment index considered;
- The VLP was calculated for the maximum contracting period, considered 25 years, common to all scenarios.

4.4 Comparison of Results

Comparing each of the previous scenarios in the table 5, it is possible to affirm that the change from the regulated market, as a captive consumer, to the ACL is favorable to the University in all cases.

Table 5. Summary of results obtained.

	Captive in 2019	**Case A**	**Case B**	**Case C**
Energy value per month	R$1.255.085,84	R$988.625,58	R$849.190,74	R$918.908,16
Energy value per year	R$15.061.030,09	R$11.863.506,96	$10.190.288,88	R$11.026.897,92
Savings per year	-	R$3.197.523,13	R$4.870.741,21	R$4.034.132,17
Savings in %	-	21%	32%	27%
Initial investment	-	R$ 0	R$760.000,00	R$ 0
Savings in 25 years	-	R$31.926.449,95	R$47.873.104,17	R$40.279.777,06

Source: Own elaboration.

With the results obtained for case B, a significant advantage can be observed in relation to the other scenarios, even with the presence of an initial investment, which is paid in the first year. This was associated with the fact that the location of the proposed plant would be in Distrito Federal, therefore, the cost of energy would be cheaper. Analyzing the concessionaires related to the state of Rio de Janeiro, the energy faress applied to medium voltage units appeared among the most expensive in the ranking provided in the MME's 2019 Fare Information. In this, Enel was in first place, while the distributor in the Distrito Federal was in the twenty-fourth (24th) position. (MME, 2021).

However, if comparing the results of cases B and C, the economic advantage of the latter added to the proximity to the location of the plant, located on the property of the University, makes this scenario the most favorable to UFF. From Table 5, it is possible to see that the savings potential for the university in scenario C, configures an approximate return of R$ 40,279,777.06 over the contract period, even with a conservative approach, with a discount rate of 10% per year.

It is also worth mentioning that this accumulated savings tends to be greater in the long term, than projected in these studies, since the readjustment incident to the regulated market rates ends up being greater than the correction index at the end of the year for the lease agreement. This is because, in addition to being subject to inflation, the cost of energy in the ACR is also readjusted in periods of drought and water scarcity. Case of the new fare flag defined by ANEEL that is in force from the second half of 2021 until the first quarter of 2022.

5. Conclusion

The presence of the free contracting environment with the possibility of generating energy for self-consumption at medium voltage through regulation as a self-producing agent is a combination that the regulated market does not offer for large

energy consumers who wish to save with the resource. It is a business model with great potential for application, as it can still be considered unprecedented in the energy market and public administration with a small percentage of associated agents.

The results of this analysis based on market values show that, if it migrated to the free environment in this model, regardless of the chosen scenario, UFF would use part of the budget normally spent on electricity expenses in the regulated market to pay the value of the lease, simply exchanging a more expensive expense for a cheaper one. During the 15-year contract period to be extended for another 10 years, UFF would have the potential to save 21% to 32% per year against the budget spent in the captive market. In the scenario used to support the business model (scenario C), the percentage savings would be 27% per year, based on an annual cost of R$11,026,897.92, and with a net present value of R$40,279,777.06 during the time of the contract.

Therefore, in the self-producer model by leasing assets, through a retail trading company, UFF becomes self-sufficient and energy secure, using 100% of the energy generated in an enterprise built specifically to meet the energy consumption of its medium-sized consumer units. voltage, and can still sell the surplus if any. In addition, by paying the specific monthly amount for the lease of the plant together with the energy management services offered by the lessor, UFF has budget predictability, without being influenced by the captive market price and variation of flags and dynamic rates. Finally, the adhesion to this type of long-term contract, with this type of energy matrix, collaborates with the construction of new similar projects, both by private and public initiative. Thus, it develops the production chain of alternative and sustainable sources, which benefit both the Brazilian economy and society.

However, it is important to emphasize that these results need to be analyzed considering the timeliness of the base data and the impact of the return of the University's on-site activities, since the defined database was the year 2019. Thus, a new potential study is suggested savings, considering the fare values for the use of the current distribution system and readjustment in the lease values, bringing together the update of consolidated consumption data based on subsequent years. Thus, reaching more precise gains that can be compared with the results obtained previously and that guarantee the security of energy supply for the University. Beyond the new study of potential economy, considering the current values, it is suggested to further works the execution of a computational project in energy production through photovoltaic generation. Using market softwares, it could be studied the existing equipment and technologies and proposed and economic arrange capable to supply the needs of the University. Also, it is suggested a study aimed at the elaboration of the basic project necessary for the construction of the plant, in order to validate the arrangement and the equipment proposed and make the project infrastructure viable, making an analysis to define if it is possible to carry it out in the land made available by the UFF in Iguaba Grande.

References

Associação Brasileira dos Comercializadores de Energia (ABRACEEL). (2021). *Consulta à Cartilha do Consumidor Livre*. https://abraceel.com.br/wp-content/uploads/post/2020/10/Cartilha-do-Consumidor-Livre-vers%C3%A3o-mobile-2.pdf.

Almeida, A. (2018). Abordagem sobre o Comercializador Varejista no Mercado Brasileiro de Energia Elétrica. *Course conclusion work (TCC) in Technology in Power Systems*. Instituto Federal de Santa Catarina.

ANEEL. *Resolução Normativa n° 77* (2004). http://www2.aneel.gov.br/cedoc/bren2004077.pdf.

ANEEL. *Resolução Normativa n° 745* (2016). http://www2.aneel.gov.br/cedoc/ren2016745.pdf.

ANEEL. *Resolução Normativa nº 482* (2012). http://www2.aneel.gov.br/cedoc/ren2012482.pdf.

ANEEL. *Resolução Normativa nº 414* (2010). 2010 p131 https://www2.aneel.gov.br/cedoc/ren2010414.pdf.

Brasil. *Lei n° 12.744* (2012). http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/l12744.htm.

CCEE. (2021a). *Consulta a dados de consumo de energia ao final de 2020*. https://www.ccee.org.br/portal/faces/pages_publico/noticias-opiniao/noticias/noticialeitura?contentid=CCEE_661134&.

CCEE. (2021b). *Consulta a queda no consumo em consequência da pandemia*. https://www.ccee.org.br/portal/faces/pages_publico/noticias-opiniao/noticias/noticialeitura?contentid=CCEE_654867&.

CCEE. (2021c). *Consulta a informações sobre o ACL e o ACR*. https://www.ccee.org.br/portal/faces/pages_publico/como-participar/ambiente-livre-ambiente-regulado.

CCEE. (2021d). *Consulta aos procedimentos de comercialização*. https://www.ccee.org.br/portal/faces/oquefazemos_menu_lateral/procedimentos.

CCEE. (2021e). *Consulta a definição dos agentes geradores*. https://www.ccee.org.br/portal/faces/pages_publico/quem-participa/como_se_dividem.

CCEE. (2021f). *Consulta a definição dos agentes associados a CCEE*. https://www.ccee.org.br/portal/faces/pages_publico/como-participar/participe/conheca_modalidades.

CCEE. (2021g). *Consulta ao Boletim InfoMercado Mensal*. https://www.ccee.org.br/portal/faces/pages_publico/noticias-opiniao/noticias/noticialeitura?contentid=CCEE_661841&.

CCEE. (2021h). *Consulta a informações sobre agentes associados em 2020*. https://www.ccee.org.br/portal/faces/pages_publico/noticias-opiniao/noticias/noticialeitura?contentid=CCEE_656483&.

CCEE. (2021i). *Consulta a base de agentes autoprodutores*. https://www.ccee.org.br/portal/faces/pages_publico/quem-participa/conheca_os_agentes.

Clemente Jr, S dos S. (2012). Estudo de Caso x Casos para Estudo: esclarecimentos a cerca de suas características. *Anais do VII Seminário de Pesquisa em Turismo do Mercosul*, Caxias do Sul – RS.

Governo. (2019). *Portaria nº 465* (2019). https://www.in.gov.br/web/dou/-/portaria-n-465-de-12-de-dezembro-de-2019.-233554889.

Governo. (2021). *Consulta aos Modos de Disputa de Licitação*. https://www.gov.br/compras/pt-br/images/ultimas_noticias/Modos-de-Disputa---passo-a-passo--05112019.pdf.

Grid Energia. (2021). *Consulta a autoprodução*. https://gridenergia.com.br/blog/fique-por-dentro-da-autoproducao-de-energia/.

Instituto Acende Brasil (2020). Evolução das Tarifas de Energia Elétrica e a Formulação de Políticas Públicas. *White Paper* 22, São Paulo, 8-10.

International. (2021). *Consulta aos dados da UFF*. http://international.uff.br/language/pt/sobre-a-uff/.

MME. (2021). *Informativo Gestão Setor Elétrico*. https://www.gov.br/mme/pt-br/assuntos/secretarias/energia-eletrica/.

Monteiro, P. R. D., & Vianna, F. S., & Silva, C. C., & Ceotto, B. N., & Nogueira, C. F., & Equipe Cice (2021). *Relatório de Acompanhamento de Energia Elétrica 2019 da UFF*. Niterói, 2021, 233 fls. Universidade Federal Fluminense, Niterói.

Pereira, E. A. S. (2019). Análise de Viabilidade da Adesão ao Ambiente de Contratação Livre e Autoconsumo em Geração Fotovoltaica. *Course conclusion work (TCC) in Technology in Electrical Engineering*. Universidade Federal do Rio de Janeiro.

UFF. (2021a). *Termo de Referência em Elaboração pela Equipe XXX e pelo programa de pós-doutorado da Escola de Engenharia*. Niterói.

UFF. (2021b). *Relatório de informações de acesso de minigeração distribuída*. Niterói.

Web of Science. (2021). *Consulta a pesquisa sobre Free Energy Market Photovoltaic*. https://www-webofscience.ez24.periodicos.capes.gov.br/wos/woscc/summary/4b4a8d70-19c8-4332-a673-eaa7c7e77f97-0492d4c5/relevance/1.