Sugar-energy bioelectricity in energy trading environments: reasons for the lack of competitiveness

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Received 28 September 2021
Revised 8 January 2022
Accepted 17 February 2022

Abstract

Purpose – Renewables such as sugar-energy biomass can contribute to national electrical security, job creation and mitigation of greenhouse gas emissions. However, after the auction of reserve energy, in 2008, exclusive biomass, in the regulated contracting environment (RCE), the authors observe that this energy environment has lost competitiveness in the auctions. Thus, a study on the present theme is justified, based on the problem: What are the reasons for the lack of competitiveness of sugar-energy bioelectricity in the Auctions of the RCE of the National Electric Energy Agency? The purpose of this study is to understand the situation of sugar-energy bioelectricity in the Brazilian market.

Design/methodology/approach – Literature review was conducted through the Scientific Electronic Library Online database, as well as the survey of primary documents at Sugarcane Industry Union and Electric Energy Trading Chamber.

Findings – The reasons for lack of competitiveness in RCE electricity auctions are: distant location of transmission lines; difficulties in obtaining licensing; delay in responses from environmental agencies; difficulties in securing financing for electricity generation projects for distilleries; non-pricing of positive environmental externalities as adequate disposal of waste; and the non-recovery of the cost of retrofit of the plants. The present situation may create economic, social and ecological circumstances adverse for Brazilian development, such as a lack of employment and income generation, loss of international currencies from imports of technologies not developed and produced in the country and more significant inefficiency greenhouse gas mitigation.

Originality/value – The originality of this study is in the contribution to the scarce literature on the understanding of the reasons for the lack of competitiveness of the Brazilian sugarcane sector in auctions of the regulated energy environment, based on SWOT analysis and, based on this understanding, to propose solutions for the expansion of this important matrix energy.

Keywords Sugar-energy bioelectricity, Electricity auctions, Regulated energy environment

Paper type Research paper

1. Introduction

Energy is one of the most important themes for sustainable development. It is estimated that 38% and 23% of the global electrical energy generation comes, respectively, from mineral

International Journal of Energy Sector Management

1750-6220
DOI 10.1108/IJESM-09-2021-0018

charcoal and natural gas, the main global warming culprits (International Energy Agency, 2020). In this context, Brazil stands out for using electricity of hydraulic origin as the main source of the national energy matrix through the use of the waterfalls at river dams. The system is considered safe and responsible for supplying factories and cities, which indirectly interferes with the competitiveness of the industrial parks and the life quality of the population, which fundamentally depends on the supply of reliable energy at a low cost and distributed in the geographical space (Gjorgievski *et al.*, 2021). In this sense, energy sources that contemplate both the economic and environmental dimensions of development have become of global strategic importance for the search for sustainable development.

Relative to Brazil specifically, the country made a strategic choice for generating electricity based on the construction of large hydroelectric power plants, highlighting Itaipu, Tucuruí and Belo Monte, which correspond to 64.9% of the electricity generation, with an offer of 422.8 TWh, which gives the country a position of global prominence in renewable energy generation. However, this type of investment brought significant environmental impacts for the region in which the spillway is located, the need for investing in large transmission lines, vulnerability to the theft of copper cables and occasional electricity losses (Energy Research Company, 2020a, 2020b). Moreover, this type of electricity generation is very dependent on a regular rain regime, especially in the summer, which has historically changed over the past ten years.

As a consequence of the scenario mentioned above, other types of electricity generation such as biomass, wind, photovoltaic and small hydroelectric stations have gained importance in the national energy matrix, given their distributed generation capacity, investment cost, startup time and complementary to the electricity generation by the large hydroelectric stations. As a statement of grounds, one may mention the wind and solar energy matrices, representing 8.6% and 1% of the national electricity generation, with growths of 15.5% and 92.2% relative to 2018, corresponding, respectively, to the generation of 55.986 GWh and 6.655 GWh (Energy Research Company, 2020a, 2020b). With the average electricity consumption of a household being 162 KWh, these energy matrices contributed to supply Brazilian homes, disregarding transmission losses and the industrial, public and commercial electricity consumption (Energy Research Company, 2020a, 2020b).

Regarding biomass, this energy matrix is available to compose the expansion of the electricity supply for the country, with sugarcane residues such as the bagasse, straw and vinasse standing out. Until the end of 2023, the installed electricity production capacity should reach 13.98 GW, representing an increase of 41.7% compared to 2013 (Silva, Marchi Neto and Seifert, 2016). Besides, the advanced cogeneration systems have a potential of 111 TWh/year of electricity surplus (17.04% of the Brazilian electricity consumption) that could be exported to the power grid, resulting in a total electricity offer of 762.3 TWh/year in 2019. Also, contributing to creating 150 times more jobs per energy unit than oil would represent 10 thousand jobs (Goldemberg and Lucon, 2007).

Given all those economic, environmental and energetic advantages, it is necessary to understand the *modus operandi* of the regulated contracting environment (RCE) in Brazil. This is a new public regulation method in which the Brazilian National Electrical Energy Agency (ANEEL) holds auctions of reserve energy exclusive from biomass involving stakeholders such as selling agents (generators, marketers and self-producers) and the distributors [who establish contracts for energy trading in the regulated environment].

The ACR was created to meet the free contracting environment (ACL). The ACL is where the independent electrical energy producer negotiates the price directly with the end consumer. The free consumer may purchase electrical energy from any energy source, including large hydroelectric power plants (CCEE, 2016). Any public agency does not

directly regulate the negotiation in the ACL, but the sales contract must be registered with the Incentivized Energy Purchase Contracts. In this environment, the usage fees of the transmission and distribution systems will be charged by the National Electricity System Operator (ONS) and by the local distribution agent. In this market, the ICMS is set daily (CCEE, 2010; Lopez, 2013).

The auctions are legal forms of procurement through bids and are based on the following premises: contracting energy for captive consumers for the lowest tariff possible and granting the investor a long-term supply contract that serves as a guarantee of revenue for obtaining financing and providing proper incentives for the expansion of electricity generation. However, it has been observed that this sugar-energy bioelectricity has been losing competitiveness in the auctions, mainly to wind energy, which has been demonstrating that the auctions seek lower electricity supply tariffs than the inclusion of alternative sources.

In view of the present contracting model, Brazil uses only 15% of its sugar-energy bioelectric potential. If it were fully used, in particular straw, bagasse, filter cake and vinasse, then the sector would have the technical potential to reach 146,000 GWh, almost seven times the volume offered in 2018, which would represent more than 30% of consumption power supply from the SIN (Souza, 2020).

On the other hand, 2018 was the third worst year in contracting new projects in auctions in the ACR for sugarcane bioelectricity, since the implementation of this type of contract in 2005. In the so-called A-4 auction of 2017, they were 28 projects that were registered, totaling 1,422 MW and ended up selling only two projects. In the 2018 A-6 auction, 25 projects were registered, totaling 1,040 MW, but only two projects were sold.

Furthermore, in the A-6 Auction in 2019, the wind matrix sold 50.3% of the contracted volume, followed by 40.3% natural gas and 9.4% of small hydroelectric plants, finally biomass, which registered 25 projects sold only 1%. At Auction A-6/2018, biomass competed in the so-called product availability, where a single natural gas thermal plant took more than 97% of the allocated demand, consequently marginalizing sugarcane bioelectricity projects (Souza, 2020).

Furthermore, between 2008 and 2018, National Economic and Social Development Bank (BNDES) investments in the generation of sugar-energy bioelectricity have been decreasing. In 2008, the disbursement was R$1.9bn, of which 29% of the total disbursed to the sugar-energy sector; in 2017, it was R$21m, 1% of the total disbursed to the sugar-energy sector. The fall in BNDES investments in this sector can be explained by not only the reduction in investments in the sugar and alcohol sector but also the loss of competitiveness in the regulated auctions promoted by the Federal Government as of 2009 (Souza, 2020).

Given the present antithesis, a study is justified about sugar-energy bioelectricity and its participation in both free energy environment and regulated environment, starting from the following research problem: What are the reasons for the lack of competitiveness of sugar-energy bioelectricity in the ACR auctions in Brazil? As the objective and fundamental theoretical contribution of the present article, we intend to understand the current situation of sugar-energy bioelectricity in the Brazilian electricity market, with emphasis on the ACR and what are the implications of the ACR for the development of biomass as a renewable energy source for the Brazilian energy matrix? As a practical contribution, we intend to equip the sugar-energy sector and its main stakeholders through a SWOT analysis regarding the organization's primary internal and external challenges for understanding the loss of competitiveness of the present electrical matrix in the ANEEL auctions.

The present work is classified as applied, and therefore, the construction of the referential was carried out through a bibliographic survey of articles in the Scientific Electronic Library

Online (SciELO), Web of Science and the databases of the Sugarcane Industry Union (UNICA) and the Chamber of Electrical Energy Commercialization (CCEE). The objective of this article is classified as descriptive/explanatory because it both describes the main stakeholders of the national electricity sector and its legal framework and analyzes the challenges of sugar-energy bioelectricity in the ACR and ACL. Concerning the study time, the present research is considered cross-sectional, given that the bibliographical reference is cross-sectional in time.

2. Methodology

2.1 Search classification

The article is classified as applied, as it analyzes sugarcane bioelectricity in the national electricity market, as well as its stakeholders, legal framework and electricity trading market. This article is considered a formal study. The object of the study is considered descriptive, as it describes the scenario of sugar-energy bioelectricity in the national electricity market, with emphasis on the ACR, as well as its stakeholders, legal framework and electricity trading market. With regard to the length of study, this research is considered cross-sectional, as the bibliographic and data survey took place in a single moment. Table 1 summarizes the methodological descriptors.

2.2 Data collection instruments

The construction of the reference was carried out through a bibliographic survey through articles in the databases of SciELO, Web of Science, Sugarcane Industry Union and Electric Energy Commercialization Chamber in search of keywords such as: Sugar-Energy Bioelectricity; Energy auctions; and Regulated Trading Environment.

2.3 Data analysis

With the information collected from the literature review, as well as from the primary documents, discourse analysis was applied, which aims to question the meanings established in various natures of scientific production, as long as its materiality produces meanings for interpretation (Caregnato and Mutti, 2006).

2.4 Proposition

For the analysis of the information obtained in the aforementioned databases, it was based on theoretical propositions, in which the objectives of this article are based on propositions that reflect on research issues, on literature review and new interpretations. Thus, the proposition of this article is as follows: The present model of new energy auctions does not favor the contracting of sugar-energy bioelectricity.

Table 1. Methodological descriptors

Category	Type
Power of the researcher to produce effects on the variables that are being studied	Ex post facto
Study object	Descriptive
Time dimension	Transversal
Research environment	Field environment
Participant's perception of research activities	Real routine

Source: Prepared by the authors (2021)

3. National electricity sector

3.1 Main entities

In 1995, Brazil's National Privatization Program was started, with the primary objective among several being to foster the participation of the private initiative in investments in infrastructure. Regarding the National Electricity System specifically, it was included in the National Development Program. Besides the privatizations and public concessions in the sector, a series of legislative measures was taken to bring legal security to the investors, as well as reorganize the institutional framework of the sector with it being incumbent upon

Objective of the article	To understand the current situation of sugar-energy bioelectricity in the Brazilian electricity market, with an emphasis on the ACR and what are the implications of the ACR for the development of biomass as a source of renewable energy for the Brazilian energy matrix
Proposition	The present model of new energy auctions does not favor the contracting of sugar-energy bioelectricity
Literary foundation	Souza (2020) Nova Cana (2019) CCEE (2019)
Collection method	Survey of articles and documents
Data analysis	Deductive inductive analysis

Source: Prepared by the authors (2021)

Table 2. Summary of objectives, propositions, literary basis, methods of data collection and analysis

Entity	Responsibilities
CNPE: National Energy Policy Council	It is an advisory body for the President of the Republic on the formulation of national energy policies and guidelines that aims, among other objectives, at the rational exploiting of the energy resources of the country, the periodic review of the energy matrix and the establishment of guidelines for specific programs (ANEEL, 2019)
MME: Ministry of Mines and Energy	The MME is charged with the formulation, planning and implementation of the actions by the Federal Government within the scope of the national energy policy
EPE: Energy Research Company	Federal public company endowed with legal personality and under private law connected to the MME It has the purpose of providing services in the field of studies and research intended to subsidize the planning of the electricity sector
ANEEL: National Electrical Energy Agency	An agency under a special regime, connected to the MME, with the purpose of regulating and inspecting the production, transmission, distribution and trading of electrical energy in compliance with the policies and guidelines of the Federal Government
ONS: National Electricity System Operator	A legal entity under private law, nonprofit, under the regulation and inspection by the ANEEL, responsible for the coordination and control activities of the operation of the generation and transmission of electrical energy of the National Integrated System (SIN)
CCEE: Chamber of Electrical Energy Commercialization	A legal entity under private law, nonprofit, under the regulation and inspection by the ANEEL, has the purpose of enabling the trading of electrical energy in the SIN and managing electrical energy purchase and sales contracts and their accounting and settlement

Source: Moura (2011)

Table 3. Main entities of the Brazilian electricity sector and their responsibilities

Evaluation dimensions	Regulated contracting environment (RCE)		Free contracting environment
Type	Reserve energy auction (LER)	New energy auction (LEN)	Free market
Counterpart	There is no contract; all consumers honor the payment to the entrepreneur via charge (EER)	Distributors	Free clients
Physical guarantee (PG)	The sale of energy in the LER attributes to the project a PG value	The sale of energy in the LEN attributes to the project a PG value	The project only has a physical guarantee if it has sold energy in the regulated environment
Competition criterion	Selling price [R$/MWh]	Cost-benefit index (ICB) [R $/MWh]	Free-market competition
Type of contract	Amount	Availability	Amount
Procurement period	20 years	20 years	Shorter periods, from 1 to 5 years
Revenue	Sold volume valued at the sales price	Fixed revenue defined at the auction	Originating from the incentivized energy sales contracts
Exposure in the short-term market	There is no monthly exposure	Exposure assumed by the distributors	Sales (-) Generation
Penalty	Annual and four-year assessment (PG vs generation) Receipt/Payment tied to the sales price	Annual and four-year assessment (PG vs generation) Receipt/Payment tied to the PLD or the fixed revenue	According to the trading rules
Risk mitigation	Reserve energy cession	Purchase of bilateral contracts	Energy balance management
Submarket risk	With no submarket risk (the contract is registered at the submarket of the generator)	With no submarket risk (the contract is registered at the submarket of the generator)	Submarket risk normally assumed by the generator
Delay	Retention of the fixed revenue	Purchase of bilateral contracts and revenue according to RES 165	Purchase of bilateral energy contracts Incentivized

Table 4. Differences between the regulated contracting environment in the reserve energy auction and new energy auction and the free contracting environment

Source: Ribeiro (2015)

the State the function of regulation and inspection of the electricity sector, severely hampered by the crisis in the 1980s.

Still in 1995, there was the enactment of Law Number 9074, referring to the stimulation to the participation of the private initiative in the electrical energy generation sector. This law is considered the initial landmark of the competition between the generators in the trading of electricity, with the emergence of the concept of Free Energy Consumer, defined as those with an electricity demand over 10 MW and voltage of 69 kV or higher (David, 2013).

After three years, the limit was reduced to 3 MW, and in 2008, the entrance of consumers with electrical demand over 500 kW was allowed as long as the purchase of electricity was

carried out from renewable energy matrices, such as small hydroelectric stations and small biomass, wind and solar power plants (Florezi, 2009). However, such sources are more expensive than fossil sources for energy generation, which stimulated the ANEEL to develop an incentive of 50% of the prices related to the usage tariffs of the electrical system (TUST/TUSD), an incentive passed on to the tariffs of the captive consumers (Tancini, 2013).

Law Number 8987 of 1995 created the necessary conditions for the Ministry of Mines and Energy (MME) along with English consulting company Coopers and Lybrand to elaborate, in 1996, the modernization project for the national electricity sector, also known as Project for Restructuring the Brazilian Electricity Sector (Chiganer *et al.*, 2002; Goldemberg, 1998; Prado, 2003). In general lines, this project had the following assumptions: realistic tariffs; privatization; competition in the generation and trading segments; de-verticalization of the sector; regulated operation of the distribution and transmission segments; and the creation of three new institutional agents, namely, the Independent Regulating Agency (that later came to constitute the ANEEL), the Independent National Operator (that came to constitute the ONS) and the CCEE, initially the Energy Wholesale Market and later the CCEE.

In 1997, with the enactment of Law Number 9478, the National Energy Policy Council and the Coordinating Committee of the Electrical Systems Expansion Planning [1] and the Energy Research Company [2] (Mattar, 2010). We systematized the functions of each entity during the governments of Fernando Henrique Cardoso (1995–2002) and Luiz Inácio Lula da Silva (2003–2010) (Chart 1).

3.2 Electricity trading environment

Electricity trading in Brazil is carried out in two contracting environments: free and regulated, having different characteristics regarding contract terms, involved agents, legal rules, electricity pricing and forms of financing.

3.2.1 Regulated contracting environment. The ACR was instituted by Decree Number 5163 of July 30, 2004, regulating the trading of electrical energy and the granting process of concessions and electrical energy generation authorizations (Magalhães, 2009). The ACR is the trading environment in which the purchase and sale of electricity among distributors and generators are carried out; thus, their projects will be consolidated through auctions through auctions.

The planning and execution of the electrical energy auctions are incumbent on the MME, charged with determining the guidelines and system of the action; on the Energy Research Company, responsible for the registration and technical qualification of the generation projects interested in participating in the auctions; on the Chamber of Electrical Energy Commercialization, charged with operationalizing the auctions; and finally, on the ANEEL, responsible for devising the public notices and the documents for the electrical energy purchase and sale contracts (Rego, 2012).

Moreover, the ACR was devised with the objective of guaranteeing the lowest price possible for small consumers, also considered as captive energy consumers, as well as not allowing them to be vulnerable to the price oscillations, which is because of the variation in the offer of electricity or for their inability to manage their contractual relations with the distributors (Palomino, 2009).

The electrical energy contracting in the ACR is performed in nine different ways, with the common objective of these auctions being the search for the smallest tariff, aiming at the efficiency in contracting electricity (CCEE, 2020).

3.2.2 Free contracting environment. The ACL is the market environment in which the purchase and sale of electricity are negotiated freely among the generators and consumers

through bilateral contracts, without the intermediation of any public body. In other words, the economic agents have the freedom to discuss the purchase and sale of energy, including terms, volumes, prices and termination fines and, with this, obtain the advantages offered by a free competition market, within the trading standards established in the ACL, always registered with the Chamber for the Commercialization of Electrical Energy. In the ACL, the usage tariffs of the transmission and distribution systems are charged by the ONS and by the local distribution agents. In this market, the ICMS is charged daily (CCEE, 2009).

The possibility of migrating from the regulated environment to the ACL is voluntary, provided that one has the minimal required voltage conditions. Up to 1995, electricity consumers needed to have a demand load equal to or greater than 3 MW and a voltage equal to or greater than 69 kV. After this date, the consumer needs to have consumption over 3 MW and at any voltage. Also, consumers with loads equal to or over 500 kW and lower than 3,000 kW may participate in the ACL as long as the electricity is acquired from renewable energy sources such as biomass, wind, solar and small hydroelectric stations (Pires, 2000).

Given the exposed, consumer migration to the ACL has a financial nature, occurring whenever the possibility of savings for the end consumer is verified. Consequently, with the consumer migrating to the free market, they must sign two contracts:

(1) distribution System Usage Contract, paying to the concessionaire the current Electricity Distribution System Usage Tariff; and

(2) the purchase of energy paid directly to the generator, with volume, price, term and other previously defined conditions.

Besides, they must prove the meeting of 100% of their loads, be it through their own generation or by contracts (Palomino, 2009).

As for the generators, they must prove the physical guarantee of 100% of the sold energy and power. The validation of the guarantee may be carried out through their own generation or the contracting of electricity generation by third parties, including by importing. Finally, the electricity distribution agents must prove the meeting of 100% of their markets (energy and power) through contracts registered with the CCEE and, as per the case, approved, certified or registered by the ANEEL (CCEE, 2009).

In summary, the main differences between the regulated and the ACLs, specifically in their primary types of auctions, are presented in Chart 2.

4. The performance of sugar-energy biomass trading in the electricity environments

Among the main renewable energy sources promptly available for trading in the free and RCEs, biomass, especially bagasse, straw and vinasse, are the ones that may readily contribute to the renewable energy demand. This is because the sugarcane supply chain and its agroindustrial system are consolidated in the country and close to the large consumer centers. In this sense, the biomass from the sugarcane industry may immediately contribute to the transition of a low-carbon economy, in consonance with the sustainable development defined by the Brundtland Report and the sustainable development goals (Schardinger *et al.*, 2012).

However, as discussed in the present article, one may observe in the past new energy auctions in the ACR that sugar-energy biomass has been losing space to other energy matrices, especially wind energy. The present situation demonstrates that, although the new energy auctions were created to encourage renewable energy while seeking tariff moderateness, they do not contemplate the socioenvironmental gains of each energy matrix.

It is known that the sugarcane industry is consolidated in the country; thus, all the technologies for electricity generation from the bagasse are promptly available by the national industry, generating jobs and preventing the outflow of foreign currency. It is estimated that it generates about 150 times more jobs than the oil industry for the same energy equivalent. Besides, sugar-energy bioelectricity is generated near the large consumer centers, preventing transmission losses and offering the appropriate disposal of the bagasse, a residue of sugar and ethanol production. Also, it has its maximum electricity generation precisely in the dry season of the southeast region of Brazil, during which the reservoirs of the large hydroelectric stations are not in full supply.

Although the legal framework of the national electricity system has advanced in the past 30 years, one may observe the difficulty of inserting the main Brazilian renewable matrix into the national market. And it is understood that electricity auctions, especially those of new energy, need to be remodeled so that they be vectors of economic and social development for the country, contributing to the formation and growth of a national energy matrix that may have global protagonism and bring foreign currency, generating jobs in Brazil (Araujo *et al.*, 2019).

To substantiate the above exposed, one may mention the Auction for the Purchase of Electrical Energy Stemming from New Generation Projects, called Auction A-4/2008, held on April 4, 2018, promoted by the ANEEL, having the participation of generation projects from biomass, wind, solar, photovoltaic and hydroelectrical. The opening value for biomass was R$329/MWh, but at the end of the Auction, the average price was R$198.94/MWh, representing a devaluing of 39.5%. Given the discount and the cost structure of electricity generation from biomass, only two projects were traded, representing 6% of the contracted volume. Photovoltaic energy was the big winner of the auction, with around 74% of the contracts, followed by wind energy with about 11% and small hydroelectric plants with nearly 10%. In total, 298.7 average MW of energy were contracted (Paranoá Energia, 2018).

In the A-4 New Energy Auction held in 2017, 220 average MW were contracted by the distributors for supply from January 2021. In this sense, biomass registered 42 projects but only traded 1. Again, the big winner of the auction was the photovoltaic source, which responded for 76% of the traded volume, while biomass only represented 4%. In the A-6 Auction of 2019, a total of 1,155 average MW was contracted; initially, the biomass source registered 25 projects at the A-6 Auction but traded energy from only 6 at the end of the process (Brasil Agro, 2018).

4.1 Challenges for sugar-energy bioelectricity growth

The low sales performance at the auctions of the trading of energy from sugarcane biomass may be explained by the non-pricing in the new energy auctions of the environmental externalities of using byproducts such as straw, bagasse and vinasse for generating electrical energy (Araújo, 2017).

Likewise, one may highlight the need for investment by sugar-energy plants in transmission lines between the electricity-generating unit and the energy distribution network, although such resources may be acquired through development banks such as the BNDES. It should be emphasized that the sector is still recovering from the economic crisis of 2008 and the governmental gasoline subsidies during the Dilma Rousseff administration (2011–2016), which substantially undermined the capital structure of the power plants.

Besides, a series of other technical, economic, financial, legal and political reasons may clarify the weak performance of sugar-energy bioelectricity, especially in the RCE, which may be explained in detail from the SWOT analysis synthesized in Table 5.

SWOT analysis dimensions	Free contracting environment	Regulated contracting environment
Strengths	Distribution system	Generator/concessionaire relationship
	Generator/concessionaire relationship	Other energy sources
	Free market	Term stability/Security
	Other energy sources	Contract security
	Contract security	Financing
	Carbon credits	Carbon credits
	Regionalization	Regionalization
	Wire tariff discount	Wire tariff discount
	Price	Energy matrix
	Energy matrix	
	Contract structure	
	Free market structure	
Weaknesses	Generation is not constant	Cogeneration technology
	Low-pressure boilers	Low-pressure boilers
	Bagasse	Bagasse
	Price volatility of the MWh	Connection
	Connection	Product/byproduct
	Financing	
Opportunities	Boilers with condensation technology	Boilers with condensation technology
	Population growth	Population growth
	Supply and demand scenario	Supply and demand scenario
	Bioelectricity scenario	Bioelectricity scenario
	Renewable sources	Renewable sources
Threats	Bad weather	Bad weather
	Bagasse	Bagasse
	Hydrolysis	Hydrolysis
	Environmental legislation	Environmental legislation
		Regulated market structure
		Penalties
		Compulsory generation

Source: Devised by the authors based on João (2010)

Table 5. SWOT analysis of the trading of bioelectricity in the free contracting environment and regulated contracting environment

Based on the aforementioned SWOT analysis, specifically in regard to the internal dimensions of the organizations, one may ascertain that the ACL has greater advantages for sugar-energy bioelectricity than the ACR, especially concerning:

- *Negotiation price of the MWh*: the negotiation price of the MWh in the ACL is of free agreement between the electricity supplies and their respective consumer.
- *Contract structure*: the contract between the involved parties is more flexible regarding supply time, electricity price and occasional fines.
- *Market dynamic*: the price of the MWh in the ACL accompanies the price determined by the supply and demand of electricity in the national electricity market.
- *Regional nature of the trading*: the electricity trading in the ACL is usually carried out between electricity suppliers and consumers in the same geographical region, which reduces the transmission losses and fosters the local economy.

However, one of the most significant weaknesses of the ACL is the long-term electricity supply contract with the distributors, which consequently allows the financing of the project with development banks such as the BNDES.

This electricity generation mode must use financial instruments which may reduce the risks of the price oscillations in the market, increasing the predictability thereof, optimizing the management of the cash flow and enabling the investment in the materialization of new projects. In this sense, one of the financial instruments that meet the interests of sugar-energy bioelectricity in the ACL is electricity derivatives, created by the *Brasil, Bolsa e Balcão* (B3). Their trading began on January 18, 2021, and 27,384 MWh were traded on the first day, totalizing 16 operations carried out by nine marketers with a financial movement of about R$7m (Meio Ambiente Industrial, 2021).

In this market, the economic agents would commit to selling or purchasing contracts of a predefined amount of electrical energy, on a determined future date, by a price fixed upon conducting the business, thus contributing to minimizing the seasonality effects of energy generation, both of technical nature and from bad weather, which consequently affect the volume of electricity generated adversely. The electricity derivatives render the volatility of the prices more predictable through hedging strategies; besides, they may provide the diversification of the business risks, leverage, a price guarantee, greater transparency and stimulus to investments in the energy sector, as the business risk will be reduced for all stakeholders.

The Securities Exchange Commission authorized the Brazilian Energy Trading Desk to issue electricity derivatives. With this new possibility, the trading of electrical energy will become more liquid. In Europe and the USA, this market is already consolidated, while, in Brazil, the changes are at the beginning, which may contribute to the strategic positioning of sugar-energy bioelectricity before this new opportunity in the national electricity market.

Another possible financial instrument with the ACL would be the creation of contracts with MWh price correction clauses when they suffer strong alterations so that the effects of the price volatility, which is considered one of the main weaknesses of the ACL, may be cushioned (João, 2010).

With regard to the competitive disadvantages or weakness for both trading environments, one may highlight the cogeneration technologies and the connection to the transmission networks. Concerning the first point, a large part of sugar-energy plants is of low-pressure boilers for generation vapor, which reduces the efficiency of the process and, consequently, the volume of electricity generation, leading to financial losses. Thus, the replacement with high-pressure boilers that would allow the condensation of the vapor, and consequently, the generation of energy with minimal bagasse use is imperative. Relative to the transmission network, it is up to the power plants the investment to interconnect their generation matrix to the interconnected electricity network; as a large part of the power plants is not connected to the network, investments are necessary.

In the ACR, the use of the sales contract as a financing guarantee is a consolidated practice and may be computed in the final price of the MWh for the purpose of financing such a project. In turn, the situation is more complex in the ACL. The development of organizational structures to manage business partnerships with high complexity degrees, such as those of partial asset property or shared connections, are imperative for entering the sector. Hence the creation of financing lines to this end by the BNDES and other development banks (João, 2010). In both cases, such investments are hampered given the decapitalization of the power plants in the face of the crisis that the sector has endured since 2008.

Based on the previous paragraphs, the sugar-energy plants have avoided investments in retrofit technology, which allows them to export to the transmission network their electricity surpluses, as well as investments in greenfield projects, which allow the production of sugar, especially for autonomous plants.

With regard to the dimensions external to the organizations, both threats and opportunities, one may observe they are practically identical for the ACR and the ACL.

In other words, given the current framework of the sugar-energy bioelectricity market, the increase in the electricity demand, the valuing of renewable energy sources, the emergence of new technologies, especially in boiler rooms, foster the growth of the sector in both markets. However, external factors such as climate changes like the extension of the dry season or the rain regime may harm sugarcane production and, consequently, the supply of bagasse, straw and vinasse for electricity generation. One may also mention the emergence of second-generation ethanol technology, which would compete for the first-generation ethanol byproducts and hamper the supply of raw material for generating electricity.

5. Renewable energy trading markets: international best practices

The reforms of the electric sector in the world started in the 1980s, where the objective was the search for tariff moderation and insertion in the renewable matrices from fiscal and financial incentives, promoting economic development and environmental preservation from the free access to the transmission and distribution systems by all players in the sector and generating efficiency gains in the industry.

The driving force behind the reforms in the worldwide electricity sector was the changes in regulatory policies guided by the following guidelines: reduction of electricity generation costs by encouraging free competition and stimulating private investment in the sector; expansion of players in electricity generation; reformulation of the operation and regulation system of the national electricity sector; decision autonomy for consumers with different levels of participation in wholesale and retail; privatization of certain generation; transmission and distribution assets of the electric sector; economic incentives for viability of the renewable matrices of energy; and deverticalization of the sector with the objective of restraining monopolistic and oligopolistic practices in the sector and, at the same time, increasing the number of agents participating in the generation and commercialization of electricity (Rosa *et al.*, 1998).

In this sense, generated electricity from renewable sources is already traded on retail markets in countries such as the USA, Germany, China and Denmark, Switzerland and Sweden.

To regard to the biogas market in China, there are average 40 million small digesters to treat animal manures, and now, the Chinese Government applies this policy toward medium and large-scale farms. In Europe, Denmark's centralized biogas system of manure co-digestion was based on entrepreneurship and farmers, followed by waste management policies and financial incentives that helped develop the sector (Coelho *et al.*, 2021).

In Germany, specifically with regard to bioelectricity, the enactment of the Renewable Energy Sources Act (EEG) in 2000, together with its amendments in 2004 and 2008, was the key policy intervention for the generation of energy and heat through biomass, which enabled an increase in biomass plants, through the economic viability of these plants from the payment of electricity generation for 20 years which is reduced by 1% per year, to maintain the profitability of these plants and, thus, achieve gradual independence (Schwarz *et al.*, 2012).

In addition to the payments above, the EEG provides additional payments for the exclusive use of renewable raw materials, cogeneration and technological innovations, aiming to optimize the generation of renewable energy. In addition to the EEG, climate change, greenhouse gases emissions, technological innovations and economic

development in rural areas and energy security can also be identified as the main drivers of bioenergy policy developments in Germany, with an estimated 122,000 jobs created in 2010.

The North American electricity sector is the largest in the world in terms of size and electricity trading, but it is not uniform in terms of organization. The Federal Government of the USA, as well as the states of the union and the municipalities, requires different structures according to their respective economic and environmental realities. The strategic objective of electricity policy in the USA has been to promote fair and equal competition for all market players, with open access to transmission as a necessary condition (Furtado, 2010).

The beginning of the insertion of renewable energy matrices in the USA began with the enactment of the Utility Regulatory Policies Act, as part of the National Energy Act. This Act sought to correct three fundamental challenges: cogenerated energy in small generating plants was not purchased by the utilities; tariffs on small generators were a barrier to entry; and trading electricity in the US market was expensive (Prado and Prado, 2006).

With the regulation of the law, the Federal Government introduced several actions, among the main ones: improvement of the US electrical system's reliability by increasing the number of renewable energy generators; compulsory purchase by the electricity concessionaires of the electricity generated by small producers; pluralization of renewable energy sources eligible for commercialization with the concessionaires: wind, solar, hydro, biomass and urban waste; increase in the efficiency of electricity generation from the insertion of cogeneration plants; and establishment of electricity prices per state (Prado and Prado, 2006).

In this sense, it can be observed that the energy policies of the aforementioned countries stand out for differentiated and favored regulatory frameworks for renewable matrices. In Brazil, although the renewable matrices have access to low-interest financing lines and access to captive markets, the country still lacks instruments aimed at the full development of its renewable energy generation capacity, such as specific regulatory frameworks for bioelectricity, regionalization of the electricity market and opening of the wholesale market for all market players.

Moreover, once such instruments are not observed in the Brazilian market, it does not incur opportunities to generate jobs and adaptability to the economic, social and environmental characteristics of each region of the country, which could contribute to a greater supply of electricity and, finally, dampen the inflationary process of the sector in the country, observed in 2021. Moreover, the restriction of a significant portion of consumers in the wholesale market, or in the free environment, reduces the growth potential of the ACL.

6. Final considerations

Based on the bibliography addressed in the present article, sugar-energy bioelectricity may contribute superlatively to constructing a carbon-free electricity complex with secured supply, especially in the dry season of the southeast region.

However, the present long-term contracting model for purchasing electricity, the ACR, does not reap the social, energy and environmental gains of the projects submitted to the auction. The other aspects that prevent biomass growth are investments in transmission lines, difficulties obtaining licenses, delays in the responses by environmental bodies and difficulties obtaining financing for electrical energy generation projects for distilleries.

The absence of the aforementioned variables has caused the curtailment of sugar-energy biomass growth in the national energy matrix, and such a situation may come to create negative economic, social and environmental circumstances for the country. Concerning the economic dimension, one must consider that the sugarcane production chain in Brazil uses cutting-edge technology. In this sense, all the investment made in constructing new biomass plants means both dynamizing a genuinely national industry and increasing the foreign currency reserves from the non-importing of products and processes from other matrices, such as wind and photovoltaic energy. Finally, the social dimension is an important factor because it has the capacity to generate 150 times more jobs in the country than the oil industry per energy unit, along with the environmental dimension, given its carbon-neutral footprint.

Therefore, the proposition of the article is considered correct by stating that the present model of new energy auctions does not favor the contracting of sugar-energy bioelectricity, and answering the question of the article of what are the reasons for the lack of competitiveness of sugar-energy bioelectricity in the auctions of the regulated energy contracting environment of the ANEEL, one may consider especially the lack of appropriate valuing of environmental attributes of biomass from the exploiting of straw, bagasse and vinasse, the exclusion of biomass from auctions dedicated only to coal and gas, the judicialization of the short-term electricity market, the investment in boiler technology and transmission lines and retrofit investments.

To overcome the present bottleneck, initiatives such as regional electricity auctions from the distributors, mitigation of the problem of connecting to the transmission lines and the creation of free-market mechanisms capable of enabling bioelectricity projects, including financing instruments and consistent price-formation in the short-term market, may contribute to valuing this energy matrix and, consequently, increasing its competitiveness in the new energy auctions of the ANEEL.

The theoretical contribution of this article, in light of the above, are that the present model of energy supply contraction in Brazil, with emphasis on the RCE, does not explore the environmental, social and economic contribution potential of the sugarcane industry, which would be remodeled, pricing the environmental and social services of this type of energy generation. Although such a measure, in principle, could increase the price of KWh for the final consumer, it would happen in the short term; however, once a robust sugar-energy bioelectric park is built, the trend would be to stabilize the tariff once its contribution, especially during the dry period in the southeast region of the country, in which the hydroelectric plants work at below capacity and the change in tariff flags could be amortized.

This situation is made even more urgent by climate change and the consequent change in the rainfall regime of the country which directly impacts the energy supply by hydroelectric plants and, consequently, the price of KWh paid by consumers.

In view of the results found in this research, the practical implications, specifically with regard to managerial inferences, with sugarcane plants and with a period of uncontracting, would be the migration of electricity generating units to the energy-free environment. Although this contracting model does not allow the formalization of long-term supply contracts, the ACL would allow these electricity producing units to generate cash flow, which could be invested in the modernization of machinery and equipment and, consequently, be able to participate in the auctions of existing energy in a more competitive way, in other words, in leadership in low cost, with the moderate price of MWh.

With regard to electricity generation projects from sugarcane biomass, aimed at new energy auctions, given the loss of price competitiveness, especially for wind and photovoltaic matrices, the managerial implication of the present reality would be the elaboration of projects with generation scale capacity, from the latest generation equipment which enables the lowest cost per MWh generated. In other words, given the non-pricing of environmental externalities in the sugarcane bioelectricity ACR, such projects are restricted to large plants, with both processing scale and investment capacity.

As political implications, this article made it clear that part of the potential contribution of sugar-energy bioelectricity, especially straw, bagasse and vinasse, is not used because of a series of challenges such as: not pricing the environmental externalities of this electrical matrix; investment in connection between the generating unit and the transmission lines of the concessionaires; inability of sugarcane mills to invest in the face of decapitalization caused by the 2008 crisis, gasoline subsidies and intervention in the electricity market during the Dilma Rousseff administration (2010–2016) and consequently without access to BNDES resources; and, finally, the absence of policies incentives for the use of renewable energy.

In this sense, it is imperative that the government prices the environmental externalities of sugar-energy biomass in new energy auctions so that this matrix can contribute with all its potential in electricity generation and, at the same time, face the electricity supply crisis in the country in 2021, slowing down inflation in the sector, generating jobs within the country and saving foreign exchange reserves against the purchase of machinery and equipment from capital goods companies within the country.

In addition, given the indebtedness of the sugar-energy industry, the aforementioned reasons, the ability to amortize investment, operation and maintenance in the RCE and the economic, social and environmental externalities of this electricity matrix, refinancing could be proposed for the indebted plants to that they can once again obtain financing from the development banks for the construction of electricity generating units.

As social implications, one can expect the dynamization of the sugar-energy production chain in the country and, consequently, the creation of direct and indirect jobs, especially in the states of São Paulo, Goiás and Minas Gerais, the largest sugar cane producers in the country. Moreover, specifically with regard to the implications for consumers, one can highlight greater security in the supply of electricity and consequently less exposure of electricity prices to variations in the price of both oil and dollars in global markets, thus dampening the inflationary process in the national electricity sector, observed in the year 2021, contributing, in view of this, to increase the purchasing capacity of both citizens and companies and governments.

With regard to the research limitations, the study was limited to the sugar-energy bioelectricity matrix and its competitive disadvantage, particularly in the regulated energy market. As future research, we suggest a more comprehensive study of sugar-energy bioelectricity within the ACL, as well as financing mechanisms for new plants with development banks, a critical variable for the development of this type of energy.

Notes

1. MME Ordinance Number 150 of May 10, 1999, published in the *Federal Official Journal* on May 12, 1999.
2. Law Number 10847 of March 15, 2004, with publication in the *Federal Official Journal* on March 16, 2004.

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