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Comparison of the Energy Markets of Colombia and Brazil

V. Vásquez, O. H. Ando and J. J. Gimenez

Abstract— *This paper presents a description and comparison of the electricity markets of Colombia and Brazil. First of all, a study of the institutional structures and free and regulated trade environments of both Colombia and Brazil is carried out, as well as the regulated user ratings and the composition of the final prices given to these consumers according to the category to which they belong and how the evolution of these tariff values in both countries has been, regarding to the free environment, the prices of the most recent auctions of these countries are verified. The economic implications that it represents for consumers are then evaluated, belonging to the free or regulated environment in Colombia and Brazil. Moving from the internal comparison through these countries, an analysis between them is carried out, in which it is shown how the stipulated taxes also generate a marked differentiation between the values paid by the consumers of electric energy of the mentioned countries.*

Keywords— ***Deregulated Energy Market, Regulated Energy market, Wholesale Electric Power, Brazilian Energy Market, Colombian Energy Market.***

I. INTRODUCTION

The electric power is one of the most frequent energy sources in the world, being of great importance for the economy and maintenance of various sectors, due to the ease of transmission and the low relative index of energy losses during the conversion processes, what has made it indispensable for modern societies [1]. In this context, electricity causes a significant impact on the socio-economic development of countries, so when a society expands its knowledge about energy sources, it improves its quality, once electric power performs functions in different fields of society, as hospitals, colleges, shopping centers, communication systems, industries, etc. [2].

Colombia and Brazil are mainly water energy matrices countries, in Colombia, this type of generation cover 68.3%, followed by a thermal generation with 30.7% [3]. Between 1997 and 1998, the country experienced a strong child phenomenon, in which the hydraulic generation had a reduction of 30% concerning demand, it went from supplying 68.3% to move to 47.81% of the energy needed. Due to the strong dependence of this source, the maximum use of the backup capacity was required with the thermal generation that reached to supply 49%, leading to the highest known stock prices in the country and generating a rethinking of the system of energy market [4]. The remaining 3.19% was supplied by unconventional sources.

Similarly, Brazil has 66.3% of hydroelectric generation and 16.7% of thermoelectric plants [5]. A large rationing of water was necessary for 2001, so a series of changes were created three years later to modify energy security, tariff forms, and universal attention; by 2012, through a provisional measure, subsequently converted into Law 12.783 / 2013, generation and transmission companies may renew concessions, while their prices are regulated by ANEEL [6].

The energy generated in both countries is transported through a National Interconnected System (NIS), which covers most of its regions, having generators scattered throughout the national territories, these are interconnected to allow energy to be reached at any place that encompasses the system, independently from the point of production, generating greater security for consumers [4] [6].

Generators, transporters, and consumers interact through energy markets, while distributors and electricity traders are also part. In both countries, the electricity business in broad strokes has two negotiation environments: regulated and free, determined by the intervention that the state performs with prices, times and forms of supply in trade agreements of energy.

The Brazilian and Colombian markets have great similarities in their structure, however, the components charged to users vary, mainly regarding taxes added to the electric power account of Brazil. To make a comparison between the markets of the two countries, the first step was to analyze their institutional structures to identify the function performed by the different organs that compose them. Afterward, the commercial environments were

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evaluated due to the importance of the characterization and criteria that determine the types of users framed in the regulated environment, from this categorization to the consumers depends on the variation in the tariffs they must pay. For the free environment, the requirements to belong and the energy values in the most recent auctions of both countries are addressed.

Afterward, the components of the energy bills of both countries are addressed both in the free trade environment and in the regulated one, addressing the values related to unit costs per generation, public lighting, and taxes. Is shown what is the impact that the generation price, taxes, sector orders, and public lighting have on the account, as well as the methodologies used to stipulate each of them.

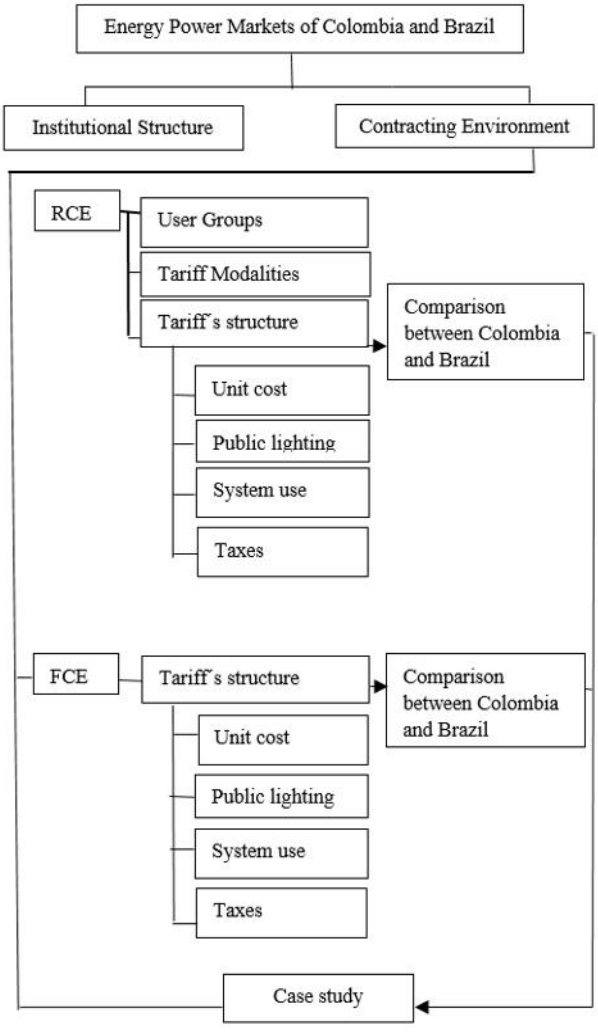

Fig.1. Flowchart of the study of the Brazilian and Colombian electricity markets.

From the evaluation of the advantages and implications that each environment has in the national spheres, goes to an international comparison, in which it is visualized, as the laws and the control carried out by the governments, generate implications for consumers.

In general terms, by studying the functioning of markets, it is evaluated as the economy when a user goes to de RTE to the FTE. The comparison of tariffs is compared both in the regulated trade environment (RTE), and in the free trade environment (FTE) of both countries, which leads to the application of these to a case study that shows the cost of energy for the Colombian and Brazilian industry in both environments, as well as the consequences of the transfer of large consumers to the free environment in these countries (Figure 1).

II. MARKET COMPOSITION

As was mentioned before, all the electric markets have generating agents, distributors, carriers, marketers, consumers and external agents [7]. The generators are the owning companies or concessionaires of the central plants of the electric energy, which could be thermoelectric, conventional hydroelectric or special units producers, that carry out the generation through wind, solar and cogeneration energy, etc. The carriers transport the energy from the generation plants to the high demand. The distributors distribute through concessions the energy in specific geographic zones to the consumers that are classified in regulated and free or specials (to buy and have free access to the prices set with the generators) [7].

In general Colombia and Brazil count with homologous structures, resulting in commercial environment with similar characteristics, the main differences are marked by the classification according to the user consumption in the regulated environment, and the required consume to be part of the free trade environment.

All the agents that are part of the markets are being governed by laws and institutions to regulate and control them, that's why it is important to understand that the institutional structures of the electric sector are fundamental for understanding the energy markets.

A. Brazil´s Institutional Structure

The Brazilian electric sector organizations (Figure 2), is governed with policies that are generated by the National Energy Policy Council and the Presidency of the Republic, through *(i)* the National Energy Research Council, *(ii)* the

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Ministry of Energy and Mines and at *(iii)* the Electricity Monitoring Committee; the facts related with the regulation and inspection are monitored by the National Agency of Electric Energy. The system operation is managed by the National Operator and the business affairs are monitored by the Electric Energy Chamber of Commerce [8]. To continue the functions of the constituent entities of the system are going to be explained briefly.

National Energy Policy Council (*Conselho Nacional de Política Energética CNPE*): Adviser of the Presidency of the Republic to formulate policies and energetic guidelines, regarding the technical, economic, social and structural aspects, with the purpose to obtain the use of energy resources [9]-[10].

Ministry of Mines and Energy (*Ministério de Minas e Energia MEM*): It is the main component of the National Energy Policy Council; its functions are the coordination and the executive secretary. [11].

Research Energy Company (*Empresa de Pesquisa Energética EPE*): It serves the Ministry of Energy and Mines through the regulation of the National Electric Energy Agency, it makes studies and needed researches to the organization of the energetic sector, including referent processes for the realization of auctions [12].

National Electric Energy Agency (*Agencia Nacional de Energia Elétrica ANEEL*): it regulates the electric sector controlling the generation, transmission, distribution and commercialization and supervising through agreements and concessions the permissions and system services according to the policies and laws from the government [13]. It also supervises and approves the process of energy commercialization made by the Electric Energy Chamber of Commerce, ONS network operating process and the generating expansion for the regulated consumers [11].

National Petroleum Agency (*Agencia Nacional de Petróleos ANP*): linked to the MME is responsible for regulating oil, natural gas and biofuels, through the promotion and regularization, trade and control of the economic activities of the industry [11].

National Electric System Operator (*Operador Nacional do Sistema ONS*): Acting under the supervision of ANEEL, it controls and coordinates the generation and transmission operations of the NIS and the isolated systems [15].

Chamber of Commerce of Electric Energy (*Câmara de Comercio de EnergiaElétrica CCEE*): through the control of ANEEL, it is responsible for making possible the purchase and sale of electric energy, managing and registering the contracts of the free trade environment and the regulated environment, promoting auctions, defines the dispute settlement price (DSP) of the short-term market for the submarket, as well as the limits for trade electric power and the penalties for such matters [16].

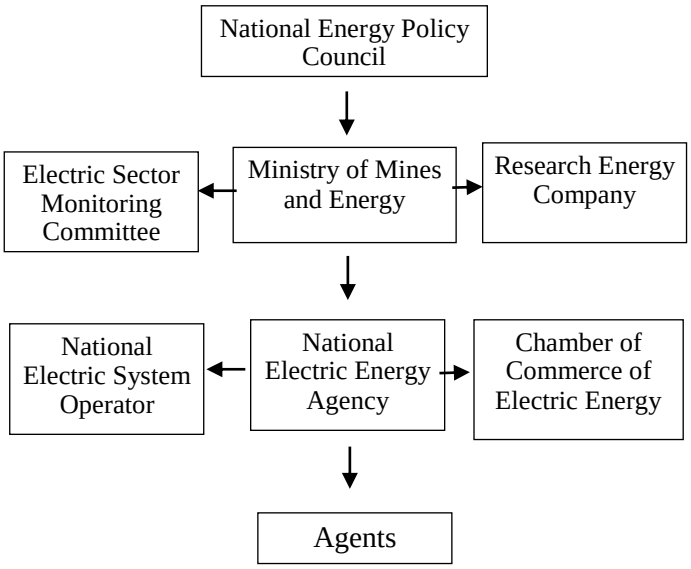

Fig.2. Institutional diagram of the Brazilian Electric Sector [8]-[14].

Electric Sector Monitoring Committee (*Comité de Monitoramento do SetorElétrico CMSE*): Evaluate the continuity and safety of the electric power supplement and its supplement conditions, accompanying the development of the activities of generation, commercialization, import and export of electric energy [14].

B. Colombia´s Institutional Structure

The Colombian electric energy market, as shown in Figure 3, is headed by the Ministry of Mines and Energy, who regulates and legislates, with the help of the Energy and Gas Regulation Commission, the Superintendence of Home Public Services and the Mining-Energy Planning Unit; The supervision of the SIN operation is carried out by the National Dispatch Center, while the administration is carried out by the Administrator of the Commercial Exchange System and the Liquidator and Account Manager of the National Transmission System.

Ministry of Mines and Energy (*Ministerio de Minas y Energía* MME):Manages resources seeking to obtain their best use by formulating, implementing and coordinating policies related to the generation, transmission, distribution and updates for the rational use of energy and the incentive to production through alternative sources [4].

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Commission for the Regulation of Energy and Gas (*Comisión de Regulación de Energía y Gas* CREG): Regulates the provision of the service and promotes the competencies of the agents providing it, making them efficient, through the preparation of bills and the regularization of the superintendence, mainly regarding tariffs [17]

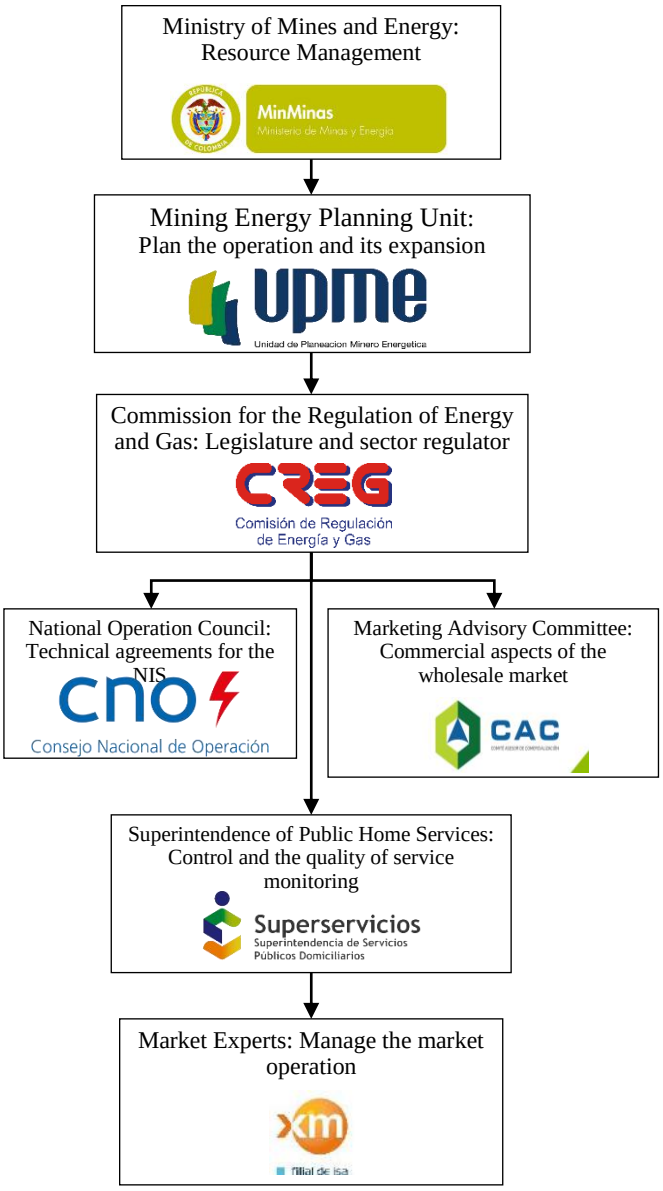

Fig.3. Main Institutions of the Colombian Electricity Sector [4] [17] - [19].

Superintendence of Public Home Services (*Superintendencia de Servicios Públicos Domiciliários SSPD*):Control and supervise the system independently of the Regulatory Commissions [4].

Mining Energy Planning Unit (*Unidad de Planeación Minero-Energética UPME*): It is attached to the MME, whose function is to plan and coordinate the agents of the electricity sector, take care of the use of resources and produce the information required for the creation of policies that support the ministry's programs [18].

National Dispatch Center (*Centro Nacional de Despacho* CND): is responsible for the planning, supervision and control of the integrated operation of the generation, interconnection and transmission resources of the National Interconnected System (SIN). Prepare the generation office and the coordination of the agents that participate in the SIN operation to have an economical, safe, reliable operation and following the operating regulations [4].

Administrator of the Commercial Exchange System (*Administrador del Sistema de Intercambios Comerciales ASIC*): Keeps records of commercial boundaries and long-term energy contracts, performs the liquidation, billing, collection and payment of the value of the energy acts or trade traded on the stock exchange of values by generators and marketers, is responsible for the maintenance of the required information systems and computer programs; of portfolio management, the management of guarantees and the fulfillment of the tasks necessary for the proper functioning of the Commercial Exchange System (SIC), through the conclusion of a contract [4].

Liquidator and Account Manager of the National Transmission System (*Liquidador y Administrador de Cuentas del Sistema de Transmisión Nacional STN*): Liquidates and invoices the charges for the use of the National Interconnected System networks that are assigned to it, as well as the regulated income to the transporters and to administer the accounts that by way of Network usage is caused to wholesale market agents [4].

National Operation Council (*Consejo Nacional de Operación CNO*): It makes the agreements of the technical aspects to guarantee that the operation of the SIN is reliable and economical, additionally, it executes the operation regulation [4].

Market Experts (*Expertosen Mercado XM*): It is a private company that performs SIN operation functions and manages the Colombian energy market [19].

III. TRADE ENVIROMENTS

The free and regulated trade environments (FTE - RTE) are a common denominator in the energy power markets of both countries, the first one is based on negotiation of the price of a certain amount of energy in a stipulated

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consumption time, through direct trades between the consumer and the generator; the second one, has state intervention for the regulation of the prices [4] [6] [20].

In Brazil, there are two modalities for becoming a FTE, (*i*) special consumers, who are required to make their agreements with special incentive sources, such as wind, biomass or small hydroelectric plants, furthermore, their demand must be equal to or greater than 500 kW and not exceed 3MW, if this value is exceeded and the voltage exceeds 69 kV, the user will be considered as (*ii*) free consumer [6] [21]-[22]. In the case of special consumers, there is the figure of "communion", in which one, when a single consumer does not reach the minimum demand required to belong to the FTE, he can join with other consumers to complete it [22]-[23].

Due to the reduction in costs for the special or free consumers, in relation to the RTE, the increase in the number of users of the FTE has been occurring exponentially. 2016 was the year that showed a greater insertion of consumers to the free environment, this meant that between 2015 and 2017, the increase represented 136%, where they were mostly special consumers [23]-[24].

The Brazilian free-market supplies more than 60% of industrial consumption and more than 30% of the country's energy [23] [25]-[26].

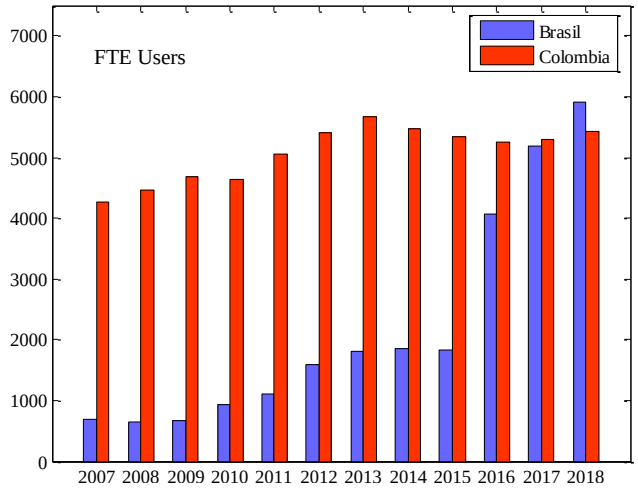

Fig.4. The number of FTE users in Colombia and Brazil [25]-[27].

For Colombia, CREG has stipulated that for becoming at the free trade environment, the minimum demand is 0.1 MW or consumption of 55 MWh-month [28]-[29].

Free buyers in the country, since 2011 has remained higher than 5000 users, without presenting large variations [27]. This fraction of buyers represents the majority of Colombian energy consumption, being in 2018, accounted for 68.3% of the energy consumed [30].

In both countries, when the contracted demand values by the free consumer are exceeded, it must go to the spot market, a short-term market with high price volatility that seeks to market surpluses and missing of the contracts, in which the operator of the market (in Colombia XM and Brazil CCEE) makes projections of consumer demand and the supply of energy of the bidders the day before its sale in a short-term auction [29] [31] - [32]. In this market, distributors also carry out transactions, both buying and selling [29] [32].

Users who do not reach the minimum demand and/or voltage levels required in both countries are forced to belong to the RTE, in which the price for energy consumption is calculated by specific methodologies that will be presented in sections IV and V.

IV. TARIFF STRUCTURE FOR BRAZILIAN REGULATED CONSUMERS

In Brazil, the tariff structure is monitored by ANEEL, who stipulates the methodology and values of the rates, these values vary according to the division of the user groups of the system based on the tensions they are served and their category.

Regarding the energy bill, this must cover the costs of generation, transmission, distribution, Governmental (Federal, State, and Municipal) segment burdens, the taxes for PIS / COFINS (Social integration Program/Contribution for Social Security Financing) the ICMS (Tax on Commodity Circulation Transactions), and public lighting [33].

On average, as shown in Figure 5, in account for regulated users, 54% corresponds to the cost of generation, transmission and burdens (TSB), 30% ICMS, PIS / COFINS and the remaining 17% to the distribution costs of the electric energy [34].

It is important to clarify that according to ANEEL (2011), the public lighting rates vary in different locations, being defined for the municipal government.

The calculation of the energy rate is defined by the concession trade between the distributor and the Union, they provide three mechanisms for the tariff update, these being the annual adjustment, the periodic tariff revision (approximately every four years) and the extraordinary revision tariff. [33].

The value to be charged to the consumer is given by equation 1.

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$$\text{Consumer Value} = \frac{\text{ANEEL´s tariff value}}{\text{1-(PIS+COFINS+ICMS)}} \quad (1)$$

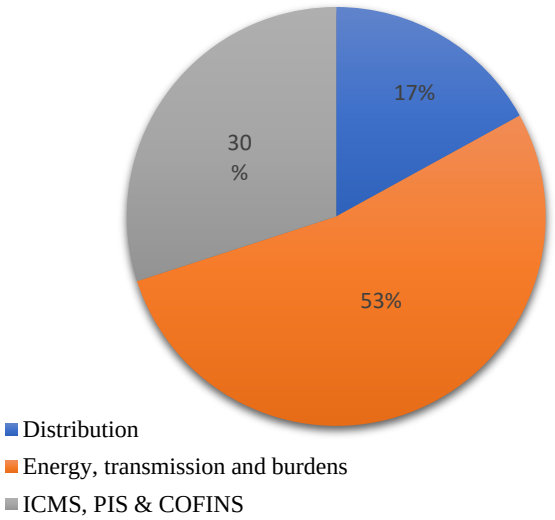

Fig.5. Brazil Energy Bill Composition Diagram [34].

The energy rate is charged in USD$/MWh and the prices vary with different factors such as peak (P) and off-peak (OP) schedules throughout the day and the applied rate modality [33].

Another determining factor in the price of the energy tariff is given by the user group in which the consumer is classified, as developed below.

A. User groups

Figure 6 shows how to differentiate network users and be able to make different user tariffs. Users are divided as high voltage groups "Group A" and low voltage "Group B", the reference value is 2.3 kV

These groups are divided into subgroups, those of group A, are divided according to the tension that will be attended, while group B depends on the kind of service, which in turn has subclasses. [35].

Additionally, and according to ANEEL, system users can also be divided as (*i*) consumers, (*ii*) generating plants and (*iii*) other distributors. By this last division, the rates will be applied by tariff modalities.

The tariff modalities refer to the set of rates for the consumption of electric energy and the demand for active power, according to figure 7 [35].

Among group A, there are two different schedules, which are cataloged according to consumption per hour:

Peak (P): In the 3 consecutive hours with higher energy consumption. Not hugging Saturdays, Sundays and national holidays [35].

Off-peak (OP): Hours complementary to the peak period [35].

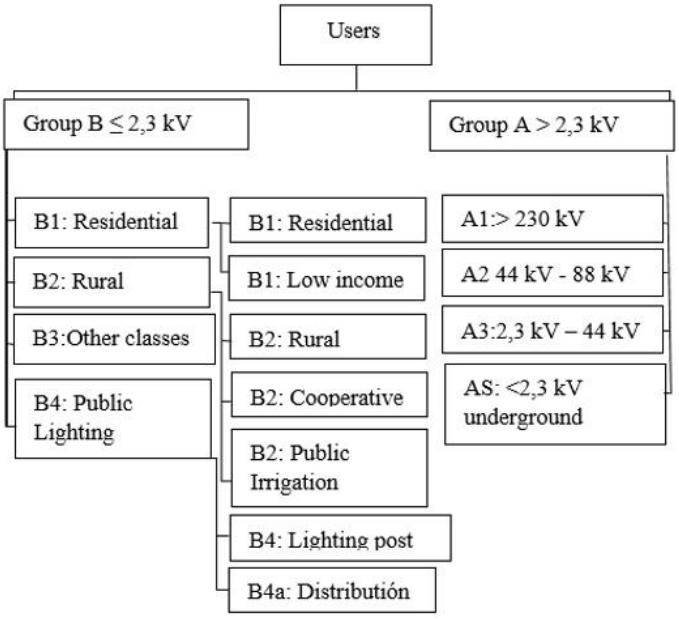

Fig.6: User Categories, Brazil[35].

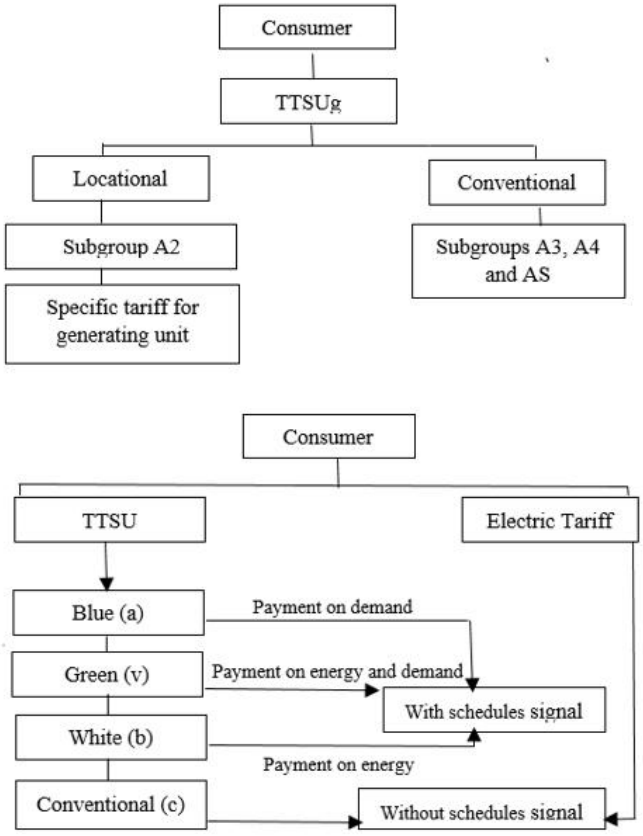

Fig.7: Tariff modalities, Brazil [35].

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Regarding group B, three positions are classified, the (*i*) Peak-hour (P) which, like Group A, is the three consecutive hours of highest consumption on day (not applicable for weekends and holidays), (*ii*) the Intermediary (I) that covers the hour immediately before and after the peak period and the (*iii*) Off-Peak (OP), referring to the remaining hours [35].

To the above terms, the seasonal factor is added to regulated consumers, in which the rate is altered according to the generation costs, by classifying three flags or levels, as shown in figure 8 [35]:

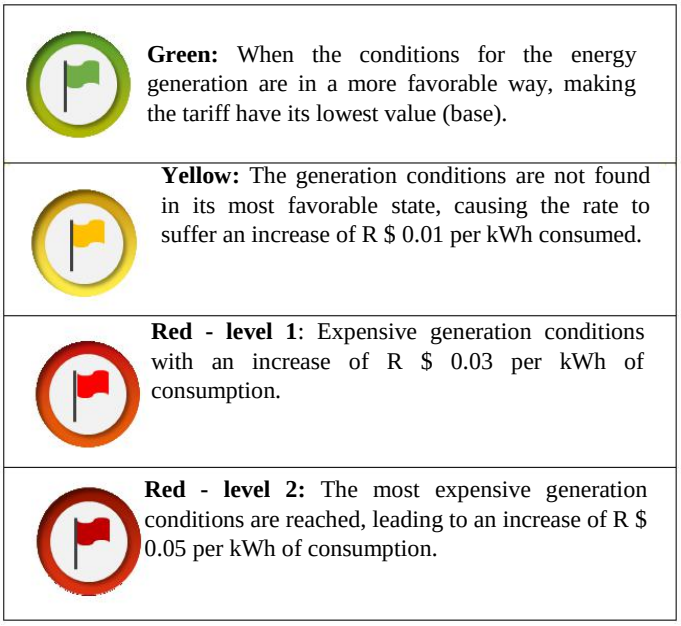

Fig.8: Energy rates according to flags and patamares [36].

B. User Bill

As shown on the COPEL website, the value to be paid by the user will be given by the equation 2.

$$AP = \frac{PL}{1-(ICMS+PIS+COFINS)} * C \quad (2)$$

AP- Amount to be paid;
C - Consumption,
PL- Public lighting rate stipulated by ANEEL;

The value referring to the ANEEL tariff is defined with all the items previously treated (the type of user, rate modality, flag, etc.).

C. Public lighting

The public lighting service is under care and administration of each municipality, so the collection of the same, it is also, since the changes in their rates must be approved by ANEEL. Figure 9 shows how the behavior and value of these rates have been between 2012 and 2018 [38].

As each city is independent of the form of collection, some choose to set a fixed time per user, but the most common methodology is to distribute the cost of lighting, according to the proportion that each user had at home [39].

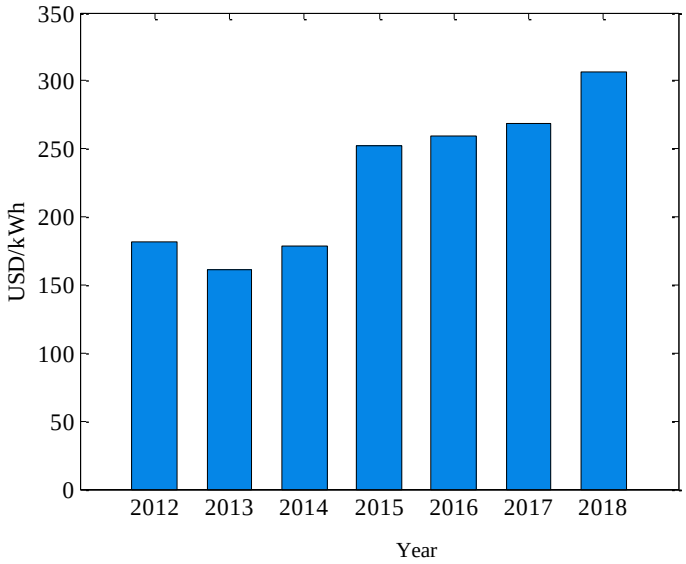

Fig.9: Evolution of public lighting rates in Brazil [38].

V. TARIFF STRUCTURE FOR COLOMBIAN REGULATED CONSUMERS

For the Colombian case, the rates are established according to CREG Resolution 079 of 1997, in which the determining factor is a socio-economic classification called “stratums", where 1,2 and 3 have a subsidy of 20% of the cost of the service that is charged for users of stratums 5, 6 and industries, stratum 4 and official agencies pay for their consumption [40].

The minimum charge for the availability of the service is charged only when the user's consumption is lower than that charge [41]. When a user is connected to the network, by CREG resolution 225/97, the connection charge is only charged once, which refers to the costs associated with the connection to the power meter. [42].

In general, in the tariff structure decreed by CREG, production, transmission, marketing, and administration costs are taken into account using formula 3 [41].

$$\text{Service Cost} = UC*\text{Consumption}+Cm \quad (3)$$

The CREG (2017) stipulates that the unit cost per service provision (UC) is calculated by the sum of the fixed unit cost

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(UCf), which is the basis of marketing and the variable unit cost (UCv), using equations 4 and 5.

$$UC = UCf+UCv \quad (4)$$

$$UCv = G+T+Cv+Lc+R \quad (5)$$

The generation charge "G" corresponds to the energy acquired from generators by traders, whether in the short-term market of the energy exchange (spot) or the long-term market, the latter is the most common [43].

Transmission cost "T", is the use of the national transmission system networks, in which the companies participating in this system are regulated by CREG resolution 011 OF 2009. The rate obtained by an annual estimate from the Invested capital, useful life, a recognized rate and income from other items [44].

Distribution cost “D” refers to the use of regional transmission system networks and the local distribution system [43].

The marketing charge “Cm” corresponds to marketers for their role as collection and intermediaries collection, as stipulated by CREG Resolution 119 of 2007, obtained by the use of the methodology of data envelopment analysis, with a margin of 15 Additional% to cover risks and invested capital and the average consumption of each invoice[43].

Through the value of the cost for losses (Lc), the marketers have recognized the intrinsic losses to the network and the equipment, utilizing estimates if there is no starting data, it is recognized 0.5% less than the operator with the lowest losses [43].

The restrictions cost “R” is made when, due to technical conditions, the operation of more expensive units is necessary than those of the optimal dispatch, having to make modifications to the generators, which leads to an operational extra cost that is determined by the system administrator of exchanges (ASIC) and applied to both regulated and unregulated users [43] .

The “Cv” is the variable component of unit cost for the service provision [43].

A. Stratification and subsidies

The stratification has the purpose to subsidize the low socioeconomic classes, classified as stratums1, 2 and, 3. They are been financed by the upper classes corresponding to stratums 4 and 5, to be intrinsic that stratum 4 corresponds to the middle class, which pays the "real" tariff value; rural areas are classified between stratum 1 and 2, while commercial and industrial entities are framed in 6 [45]. The contribution to the tariff is given in the table I.

Table I: Payment on the UC Tariff for the Stratums in Colombia.

Stratum	***Payment over the rate***	***Contribution/Subsidy***
1	0,50	50% Subsidy
2	0,60	40% Subsidy
3	0,85	15% Subsidy
4	1,00	Without subsidy or contribution
5	1,20	20% Contribution
6	1,20	20% Contribution

B. Street lighting

The public lighting service is the responsibility of the municipalities or districts, that is, the municipalities have the autonomy of quality and costs of providing the service, but must be governed by a minimum of technical criteria and a maximum price regulated by the state, calculated as enough to remunerate service providers [46].

For the most part, like the electricity consumption rate, the public lighting service is charged according to the rate criteria of the constituent class or stratum, as shown in Tables II and III.

Table.II: Public lighting tariff for Non-Residential Sectors, Colombia.

Taxpayer Class		***Monthly consumption (kWh/month)***	***Tax rate (% by consumption)***
Commercial	Level 1	< 1.000 k	6,0
	Level 2	1.000 - 2.000	6,5
	Level 3	2.001 - 5.000	6,6
	Level 4	5.001 - 10.000	6,8
	Level 5	10.001 - 50.000	7,0
	No Reg.	>50.000	8,5. Maximum 9 CMMLS
Industrial	Level 1	<2.000	6,0
	Level 2	2.001 - 4.000	6,1
	Level 3	4.001 - 10.000	6,3
	Level 4	10.001 - 20.000	6,5
	Level 5	20.001 - 50.000	7,0
	No Reg.	>50.000	8,5. Maximum 9 CMMLS
Official	Level 1	≤500	6,0

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	Level 2	501 - 1.000	6,5
	Level 3	1.001 - 2.000	7,0
	Level 4	2.001 - 10.000	7,3
	Level 5	>10.000	7,5. Maximum 9 CMMLS

*Current Monthly Minimum Legal Salary.

Table III: Public Lighting tariff for Residential Sectors, Colombia.

Strat.	***Consumption ≤ 250 kWh***	***Consumption > 250 kWh***
1	2,5% of the consumption value	6,0% of the consumption value
2	3,0% of the consumption value	6,0% of the consumption value
3	4,5% of the consumption value	6,0% of the consumption value
4	5,0% of the consumption value	
5	6,0% of the consumption value	
6	7,0% of the consumption value	

VI. COMPARISON BETWEEN ELECTRICAL TARIFFS IN THE RTE OF COLOMBIA AND BRAZIL

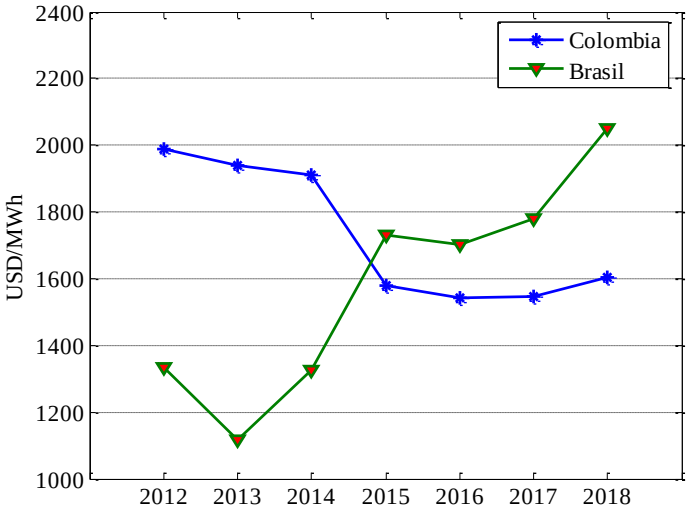

Fig.10: Unit costs of electric power in Colombia and Brazil, 2012-2018 [38] [48]–[61].

During the first years of the decade, the unit cost of electricity, was considerably lower in Brazil, compared to Colombia, a relationship that already was investedby 2015, as evidenced in Figure 10. Among the main reasons for this change, highlights issues of subsidies in the Brazilian government.

UC´s include losses related to energy transport processes. According to the data that in 2017 showed in the Rapporteurship of the World Economic Forum (WEF) on a 0-1 scale, as shown in Table IV, Colombia is ranked eighth worldwide in energy architecture, with a 0.75 score, as Brazil ranks 30th with 0.7 scores [47]. This shows that the quality of the infrastructure of the Colombian sector, allows energy losses to be lower.

Table.IV: Countries with better and worst Electrical Architecture, according to the WEF 2017.

Rank	***Country***	***Score***
1	Switzerland	**0,80**
8	Colombia	**0,75**
15	The United Kingdom	**0,72**
28	Argentina	**0,70**
30	Brazil	**0,70**
33	Netherlands	**0,69**
40	Chile	**0,67**
44	Mexico	**0,66**
45	Japan	**0,66**
52	The United States	**0,65**
76	South Africa	**0,58**
82	Honduras	**0,56**
87	India	**0,55**
95	China	**0,53**

A. Electric bills

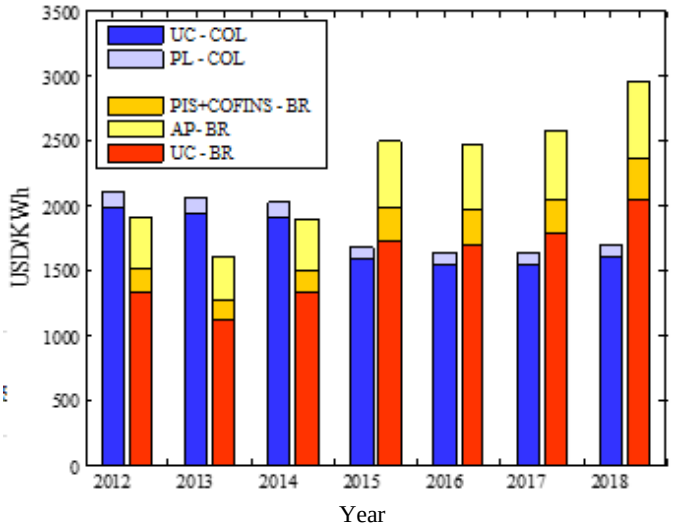

Fig.11: The total cost of electricity in Colombia and Brazil, 2012-2018. [33][38][46]–[58].

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When the electricity bill is studied as a whole, includes both public lighting services and aggregate taxes, it is denoted that, with the exception of 2012 and 2013, throughout the decade, the price of the Electricity in Brazil has been higher, creating a growing gap in the price of tariffs between the two countries, as shown in Figure 11.

It is important to bear in mind that the Unit Cost (UC) for users of the electric service includes the values related to the generation, transmission, commercialization, losses, and restrictions [52].

VII. TARIFF STRUCTURE FOR FREE CONSUMERS IN BRAZIL AND COLOMBIA

Colombia and Brazil have similarities in the aspects that differentiate the composition of the tariffs between regulated and free users, since in both cases the variation is given by the price of the energy acquired [21].

A. Brazil

From the foregoing, it is understood that in Brazil, the FTE consumer will also be obliged to pay the values related to the losses of the NIS, the System Service Burdens (SSB), DSUT (Distribution System Use Tariff), TSUT (Transmission System Use Tariff), PIS / COFINS and ICMS [21] [62].

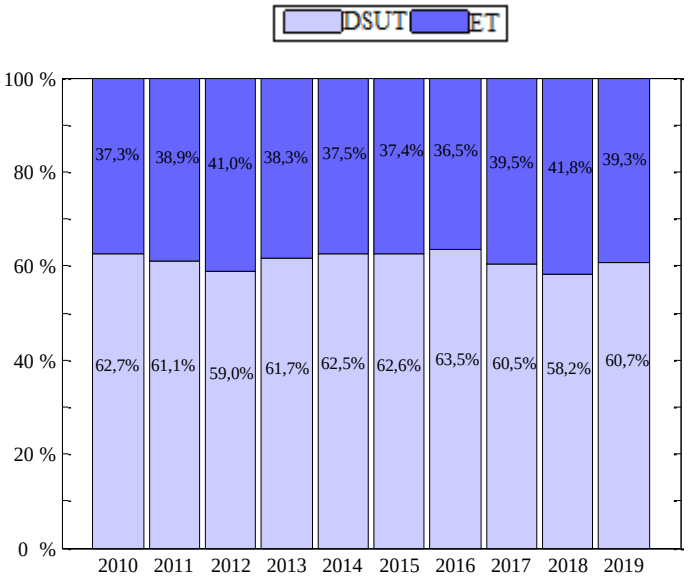

Fig.12: Relationship between the Price of the Electric Tariff (TE) and the Tariff for the Use of the Distribution System (TUDS) [63].

Table.V: Public auctions in Brasil, 2018.

Auction date	*Energy Amount (MWh)*	*Monetary Amount (USD Millions)*	*USD (million) /MWh*
04/04/2018	54.094.749,60	**1804,86**	*33,36*
31/08/2018	168.033.684,00	**6330,65**	*37,67*
07/12/2018	70.176,00	**2,68**	*38,24*
07/12/2018	6.298.296,00	**271,80**	*43,15*
TOTAL	228.496.905,60	**8.410,00**	-
AVERAGE	-	-	*38,11*

Figure 12 shows how approximately, the DSUT represents 32.1% of the total account - equivalent to approximately 60% value composed of DSUT and ET -, it is also important to take into account that on average, the ICMS, PIS and COFINS almost 30% total payment value [34] [64] - [63].

During 2018, four public auctions were held in Brazil, which totaled 8,408.67 million dollars, as shown below [65].

B. Colombia

In the Colombian case, approximately 50% of the price of energy consumption corresponds to the generation value and the other 50% to transmission and distribution costs (Figure 13), the latter being fixed, cannot be negotiated, which means that the possibility of saving is - as in Brazil –under the cost of the purchase made with the generator [66].

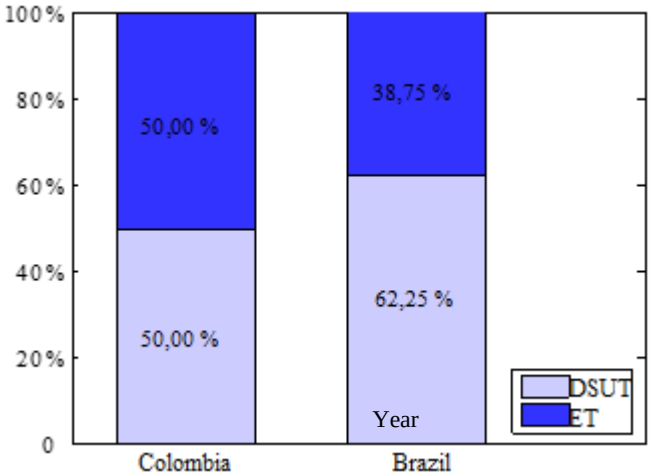

Fig.13: Average Relationship between the Prices of the Electric Tariff (ET) and the Distribution System Use Tariff (DSUT) of Colombia and Brazil between 2010-2019 [63] [66].

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During 2018, no public auctions were held, however, in February 2019 a 2022-2023 obligation allocation auction was held, in which they were awarded for a total of 69 generation units, 250.55 GWh-day, with a closing price of USD 15.1 / MWh [67] - [68].

VIII. CASE STUDY

To compare the energy markets of both Colombia and Brazil, four scenarios are carried out. The first shows the cost of active power consumption in Colombia previously specified, under the average prices of the energy traders, that is, under the condition of the regulated market, for this, an average of the annual cost of kWh in the country is obtained. A second scenario, this time considering the price under the considerations of a free consumer. Similarly, scenarios three and four will correspond to the same conditions, given in Brazil.

To make a comparison between the different scenarios, the average of the prices of the year 2018 of the marketers and the auctions of Brazil and Colombia is taken.

Based on the previous results, a comparative analysis is carried out between the types of internal markets of each country and subsequently, a comparison between the regulated and free markets of Colombia and Brazil.

The scenarios are made based on the consumption data of the Colombian company Cervalle and the calculations on the energy markets that are applied on this land, are carried out by what is presented between sections III and VII.

The Cervalle company, which has multiple pig farms distributed mainly in the department of Valle del Cauca, as well as different points of sale, among which two stand out in the city of Cali, has an approximate monthly active power consumption of 152,280, 9 kWh on farms and 27,667.71 kWh of commercial premises, according to data supplied by the company.

The data corresponding to the consumption in each of the establishments, organized according to the monthly energy consumption of each unit, are taken as shown in table VI.

Table.VI: Consumption of power Energy of the Cervalle´S Establishments.

Establishment	Consumption (kWh)
Cachorros Farm	28066,67
Sell Point 1	20896,38
Piedras Gordas Farm	19362,80
Margaritas Farm	18368,67
Cristalina Farm	12896,50
Esmeralda Farm	9792,00
Ponderosa Farm	8593,50
Arenal Farm	8118,00
Sell Point 2	6771,33
Esperanza Farm	6500,00
Guacari Breeding Farm	5866,50
Porcilandia Breeding Farm	5780,00
Bacori Farm	5110,25
Arrayanes Farm	4621,64
Porvenir Farm	3375,00
Guacari 1 Pre-bait Farm	2294,00
Flores amarillas Farm	1915,50
Bellavista Farm	1850,00
Genesus Breeding Farm	1840,67
Sortilegio Farm	1736,33
Paz De La Honda Farm	1293,00
Guacari Ceba Farm	1184,50
Santa Lucia Breeding Farm	995,25
Loma Linda Breeding Far	789,00
Guacari 2 Pre-bait Farm	748,75
Esperanza Ceba Breeding Farm	700,00
Campo Alegre Breeding Farm	281,33
Villarica Breeding Farm	184,75
los Naranjos Breeding Farm	16,33
TOTAL	**179948,70**

A. Scenario 1: Regulated Market in Colombia

To Colombia´s case, since it is a pig production company, Cervalle farms are into the industrial category, as points of sale enter the commercial one, based on the average value of consumption rates per MWh in the country during 2018, as well as the value of public lighting assumed by some municipalities, such as Cajicá shown in Tables I and II.

Thus, first, in Table VII, the establishments are cataloged to determine the additional tax to be paid.During 2018, the unit cost (UC) for regulated users was 1605 MWh [60] - [61]. Additionally, taking into account the Sections VA and VB, the values of subsidies (Sub) and public lighting (PL) are calculated and the transmission and distribution burdens (TDB) orders are approximated to the UC price, to arrive at the total monthly price of consumption of the company, shown in Table VIII.

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Table.VII: Category, level and tax of the establishments

Establishments	***Consumption (kWh)***	***Category***	***Level***	***Tax (%)***
Cachorros Farm	28066,67	Industrial	5	7,0
Piedras Gordas Farm	19362,80	Industrial		
Margaritas Farm	18368,67	Industrial		
Cristalina Farm	12896,50	Industrial		
Esmeralda Farm	9792,00	Industrial	4	6,8
Ponderosa Farm	8593,50	Industrial		
Arenal Farm	8118,00	Industrial		
Esperanza Farm	6500,00	Industrial		
Guacari Farm	5866,50	Industrial		
Porciland Farm	5780,00	Industrial		
Bacori Farm	5110,25	Industrial		
Arrayanes Farm	4621,64	Industrial	3	6,6
Porvenir Farm	3375,00	Industrial		
Guacari 1 Farm	2294,00	Industrial		
Flores A Farm	1915,50	Industrial	2	6,5
Bellavista Farm	1850,00	Industrial		
Genesus Farm	1840,67	Industrial		
Sortilegio Farm	1736,33	Industrial		
Paz de Ho. Farm	1293,00	Industrial		
Guacari Farm	1184,50	Industrial		
Santa L. Farm	995,25	Industrial	1	6,0
Loma L. Farm	789,00	Industrial		
Guacari 2 Farm	748,75	Industrial		
Esperanza Farm	700,00	Industrial		
Alegre Farm	281,33	Industrial		
Villarica Farm	184,75	Industrial		
Naranjos Farm	16,33	Industrial		
Sell Point 1	20896,38	Commercial	5	7,0
Sell Point 2	6771,33	Commercial	4	6,8
TOTAL/AVERAGE	**179948,70**	-	-	**6,8**

Table.VIII: Costs for Regulated market in thousands of USD, Colombia.

Establishments	***UC***	***Pl***	***Sub.***	***TDB***	***Total***
Ind. Level 5	126,30	8,84	25,26	126,30	286,71
Ind. Level 4	79,87	5,43	15,97	79,87	181,13
Ind. Level 3	16,52	1,09	3,30	16,52	37,43
Ind. Level 2	15,76	1,02	3,15	15,76	35,70
Ind. Level 1	5,96	0,36	1,19	5,96	13,48
Com. Nivel 4	13,79	0,97	2,76	13,79	31,31
Com. Nivel 3	13,03	0,89	2,61	13,03	29,55
TOTAL/AVERAGE	**271,23**	**18,60**	**54,25**	**271,23**	***615,31***

B. Scenario 2: Free market in Colombia

For the unregulated market, the price of the 2019 debt allocation auction, which was 15.1 USD / MWh (Section VII-B), is taken as a reference, with this value and approximately 179.95 MWh required by the 180 MWh company, the price of energy consumed in the FTE is calculated. Additionally, it is taken into account that the costs of public lighting, subsidies payable, TTSU and DTSU(TDB) remain independent of the trade environment, that is, they are the same as those resulting in the regulated market.

Table.IX: Costs for Non-Regulated Market, Colombia.

Item	***Cost(Thousands of USD)***
Consumption (MWh)	180
Unit cost (USD/MWh)	15,1
Consumption Payment (Thousands of USD)	2,7
Public L. payment (Thousands of USD)	18,6
Subsidies payment (Thousands of USD)	54,25
TDBPayment(Thousands ofUSD)	271,23
TOTAL (Thousands of USD)	**346,78**

C. Scenario 3: Regulated Market in Brazil

To obtain the value that the CERVALLE company would have to pay for its energy consumption in the Brazilian regulated market, it is necessary to take into account that in addition to the UC per kWh and public lighting, the PIS and COFINS represent a considerable fraction of the bill.

The farms belong to subcategory B2, which refers to the conventional rural rate, this subgroup in 2018 had an average rate of $1.2839 USD / kWh; As for the points of sale, they correspond to B3, a conventional industrial reference, its average price was $1.9876 USD / kWh and finally B4, of public lighting (PL), $1.7735 USD / kWh, in the latter, as it turns out impossible to know the consumption of public lighting and consequently divide it proportionally to the consumption of the establishments, 10% of the total internal consumption is considered randomly [69] - [70]. Finally, section IV is taken into account, that PIS / COFINS and ICMS (PCI) represent approximately 53% of the account and transmission burdens (TDB) 17%.

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Table.X: Costs for regulated Market in thousands of USD, Brazil.

Group	*UC*	PL	PCI	TDB	*Total*
B2	162,36	19,6	242,57	33,15	*457,68*
B3	41,32	5,5	68,11	13,58	*128,51*
Total (Thousands of USD)	**203,68**	**25,1**	**310,62**	**46,73**	***586,19***

D. Scenario 4: Free market in Brazil

For the unregulated market in Brazil, the approximation of 180 MWh was also taken, and for the prices perKWh in this trading environment, the average of the public auction values carried out during 2018 in the country was taken (Section VA), which resulted in an average of $38.11 USD / MWh, however of this value, is separated from the UC, the cost of the TUDS in accordance with the 2019 ratio shown in Section VII. Also, as discussed in the same section, the values of the RTE of public lighting and PIS / COFINS and ICMS, which totaled $ 343.39 thousand of dollars.

Table.XI: Costs for Non-regulated Market, Brazil.

Description	***Cost (Thousands of USD)***
Consumption (MWh)	180
Unit cost (USD/MWh)	38,11
Payment for consumption (Thousands of USD)	6,86
Public lighting payment (Thousands of USD)	25,1
Subsidies payment (Thousands of USD)	310,62
TUSD payment (Thousands of USD)	46,73
TOTAL (Thousands of USD)	**389,31**

E. Results Comparison

The results showed that, in Colombia, the Cervalle company having an approximate consumption of 180 MWh / month, it has a monthly expense of $615.31 thousand dollars in the regulated market, being considered the energy supplement points as stratum 6, including the values related to public lighting and subsidies that should be considered for this classification, as well as orders for the use of the system (Table VIII). If this same company makes the migration to the FTE, it would pay in the same period and for the same consumption, USD $ 346.78 thousand dollars (Figure 14), which includes the same value paid for lighting, subsidies, transmission and distribution, but a different value to the energy rate (Table IX). With this, a reduction of almost 43.65% is shown (Figures 14 and 15), which would represent $ 268.53 thousand per month and $ 3,222.36 per year.

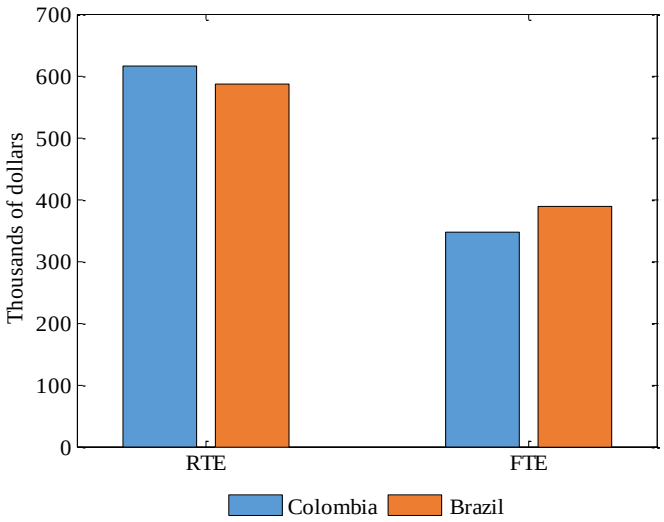

Fig.14: Comparison in thousands of dollars between the costs of the monthly energy consumption of the Cervalle Company in the CERs and FTEs of Colombia and Brazil.

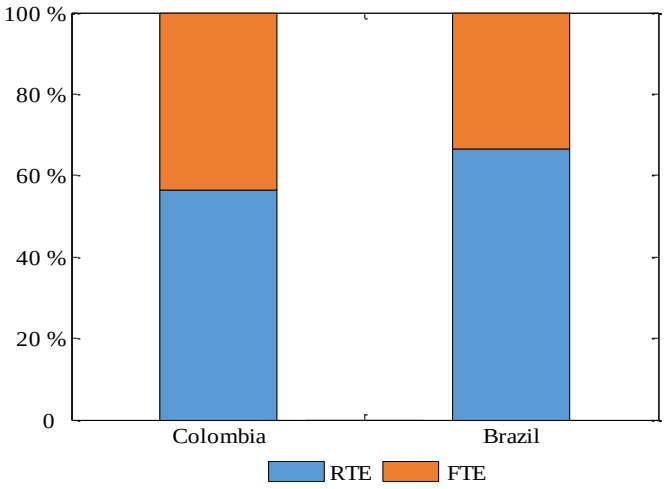

Fig.15: Percentage comparison between the costs of the monthly energy consumption of the Cervalle company in the FTE, about the RTE.

A similar phenomenon would occur in Brazil, which would go from paying $586.19 thousand dollars per month to $389.31 thousand dollars per month to $180MWh / month. Considering that the value of lighting, taxes and system use remain constant, find the rate varies between the two environments (Table X and XI). For this reason, the change to the FTE would imply a 33.59% decrease in economic

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spending, which would be equivalent to 196.88 thousand dollars per month and 2,336,560 annually.

Comparatively, in the RTE of Colombia, as companies are considered stratum 6, there is a 20% increase in the rate (in relation to the real value, which is represented by stratum 4), causing that, in comparison with the results of Brazil, the cost of energy is higher, however, and despite having to make the same amount for subsidies, when it is passed to the FTE, the price of Colombian energy is almost 11% cheaper than in Brazil. This implies that when a company moves from the RTE to FTE, in Colombia it has a greater margin of savings related to the payment for electricity consumption.

It is perceived as in Colombia the consumption itself goes from representing 44% of the payment value of the invoice when the company trades its supply in the regulated environment. This consumption happens to represent less than 1% of the account in the FTE, where the payment for the use of the system is the most representative fraction in the payment, covering 78% of the total cost for the energy supply (Figure 16).

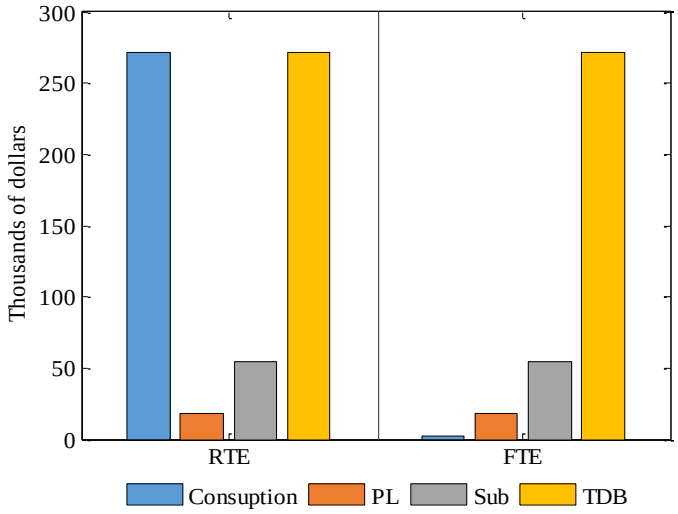


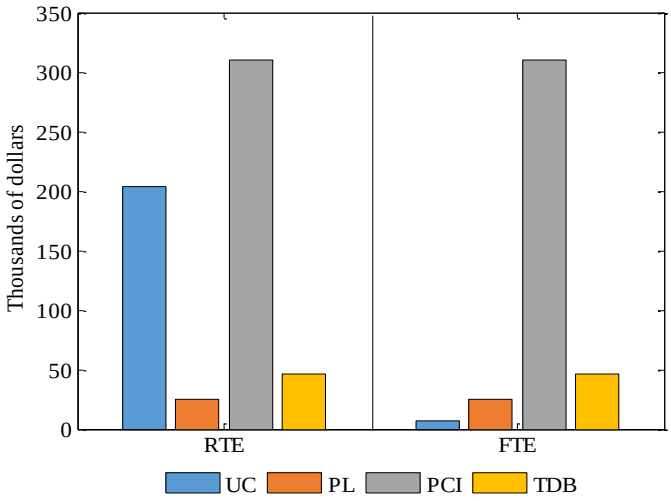
Fig.16: Differentiation of the tariff paid in the RTE and FTE, Colombia.

This shows how the concessionaires and distributors have a high impact on electricity rates, because when considering that (*i*) the values paid for lighting, system uses and taxes are fixed, and assuming that, (*ii*) these buy the energy in large volumes, with prices similar to those of public auctions, it results in the reduction of approximately 43.6% in the invoice as a whole when the energy is purchased from the FTE, refers to the payment for the services of the concessionaires and distributors. When we look specifically at the cost per consumption, we see that from $2.7 thousand dollars, it goes to $271.23, this is 100.45 times more than the value of the auction.

It was identified that, in Colombia, the cost given by the use of the system is comparatively very high, while in Brazil the plot corresponding to taxes is the one that represents the excessively high cost, comparatively (Figures 16 and 17).

In Brazil, for both the free and regulated trade environment, the largest fraction of the energy bill is related to taxes (PIS / COFINS and ICMS), here the change from the RTE to the FTE, makes consumption pass to represent 34.7% of the total invoice to 1.8% of this (Figure 17).

Similar to Colombia, it is denoted that the concessionaires and distributors have a high impact on electricity rates, since it is considered that with the exception of consumption, the other constituent rates of the bill remain constant and that these entities also buy energy at a price approximately equal of public auctions, implying that the reduction of approximately 33.6% in the total of the account, is related to the payment given to these entities for the provision of their service. At the same time, when looking specifically at the cost per consumption, we see that the value of $6.86 thousand dollars is 29.7 times higher in the CER (203.68 thousand dollars).



Figu.17: Differentiation of the tariff paid in the RTE and FTE, Brazil.

IX. CONCLUSION

Organizationally and functionally, the energy systems of Colombia and Brazil are very similar, both in the functions of

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the institutions that compose them, and the fact that the two have trade environments: regulated and free.

The differences arise primarily in the requirements to be able to purchase the energy directly with the generators that allow a decrease in the total cost of energy.For Brazil, it is necessary to have a demand over 3 MW and a voltage over 69 kV to be a free consumer or, between 500 kW - 3 MW to be a special consumer, where you can make direct contracts only with unconventional sources of energy generators. For its part, in Colombia there is no special consumer figure and, but belonging to the free trade environment, a minimum demand five times less than special users is required, that is 0.1 MW or consumption of 55 MWh-month.

From the above and adding that one of the most striking differences in the comparison between the markets of the two countries is that while in Colombia there is a tendency to decrease the UC of energy, and Brazil is increasing rapidly, what can be understood because in Colombia the number of free consumers has remained at a high and relatively constant number during the last two decades, while the number of users of the FTE of Brazil has presented a dramatic increase, mainly marked since 2016, exceeding in 2018 the amount Colombian.

The other big difference that can be observed between commercial systems is the regulated user´s categorization and the implication that it has on the cost of energy for them. In Colombia there the classification system is the stratification, in which stratum 1-3 are subsidized between 15% and 50% by stratum 5-6, which, pay an additional 20% on the value of the ET and stratum 4 pays the real price of energy; the industrial and commercial sectors are considered as stratum 6, consequently having financial repercussions on them.The classification in Brazil is more complex and based mainly on the voltage levels that are served by the consumer, being first classified as low (B) voltage, when it does not exceed 2.3 kV and high (A), when this value is exceeded; then consumers B are subclassified according to the destination of the use of energy (residential, rural, lighting, etc.), like those of group A, are again divided according to tensions. Although these classifications generate a difference in prices between users, unlike Colombia they do not have a specified percentage of increase or decrease in the ET, but their prices are regulated by limits imposed by ANEEL.

The value of energy in Colombia is given by the cost of generation, transmission orders and in some cases a fraction practically disregard taxes, while in Brazil, taxes cover more 50% of the final value of the tariff in the CER, making the average cost of energy much higher comparatively. However, through the case study, it is shown how the increases given according to classifications such as subsidies can to affect and reach the value paid by Brazil.

Another factor that strongly affects the price of energy in Brazil, is given by the “seasoning factor”, where regulated consumer rates are affected by the flags, which they are defined by the conditions of generation, going from the most favorable to the most expensive of them respectively increasing over the tariffs that go from R$ 0.01 - to R $ 0.05 per kWh of consumption.

All these components that catalog users, in the case study of the controls that, although Colombia has much lower energy rates than Brazil, these for the industrial and commercial sectorsis not reflected, because paying subsidies, resulting even - 5% - cheaper for users in the Brazilian regulated market.

The savings in the free trade environment, in both cases, comes from the decrease in the rate that would be paid to the concessionaires and/or marketers, since the payment of taxes, public lighting and use of the system remain constant regardless of the trade environment. The increase given by concessionaires and/or marketers, is raised almost 30 and 100 times in Brazil and Colombia respectively.

It was perceived that approximately total energy payment values vary between countries with approximately 10% in the FTE in favor of Colombia, this is given for the price given in the use of the system that was highly expensive in relation to Brazil

In an ideal scenario, in which users buy exactly the amount of energy needed, it was observed that the Brazilian users who make the purchase of energy in the FTE, that pay approximately 66.4% of the value paid for the same consumption in the RTE. Similarly, the Colombian user who goes on to negotiate at the FTE pays approximately 56.4% of the value of energy compared to its price as a regulated user.

With all of the above, it was identified that, in Colombia, the cost given by the use of the system is comparatively very high, while in Brazil the plot corresponding to taxes is the one that represents the excessively high cost, comparatively. Additionally, it is denoted that the price of the energy at which distributors and / or concessionaires buy and, the price at which it is sold to the user, is high multiplying this value by several tens.

The knowledge of these systems allows large (industrial) consumers to reduce the costs related to energy consumption due to the possibility of changing trade environments, consequently bringing economic risks to the same countries.

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Also, a comparison between countries allows these studies possibilities for improvements, identifying the factors that increase price variations in the market, to consumers, leading to greater competitiveness.

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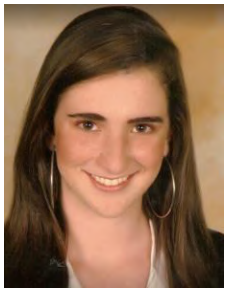

Valentina Vásquez Arangois an Energy Engineering and Master's student in the Interdisciplinary Pos-Graduation Program in Energy and Sustainability of the Federal University of Latin American Integration - UNILA. Research area: Electricity markets, Biorefineries and Biogas.

Oswaldo H. Ando Junior. Graduated in Electrical Engineering (2006) with a Specialization in Business Administration (2007) from the Lutheran University of Brazil - ULBRA with Master's Degree in Electrical Engineering (2009) from the Federal University of Rio Grande do Sul - UFRGS and Ph.D. in Mining Engineering, Metallurgy, and Materials of the Federal University of Rio Grande do Sul - UFRGS (2014). He has engineering experience working on the following topics: Energy conversion, electrical energy quality, electrical energy systems, residual energy capture, and energy efficiency. Associate Editor IEEE Latin America Magazine. Member of the Review Committee of several journals: Renewable Energy Focus (Elsevier) and IEEE Latin-American Magazine.. Ad hoc consultant FAPESC, Advisory Committee Area of the Araucária Foundation (CAA), ad hoc consultant CNPq, ad hoc advisor I + DI of the National Power Energy Agency (ANEEL).

Jorge Javier Giménez Ledesmahas a degree in Electromechanical Engineering from the University Nuestra Señora de la Asunción (2009), a master's degree (2012). and Ph.D (2017) in Electrical Engineering from the Federal University of Juiz de Fora. Adjunct Professor at the Federal University of Latin American Integration. He works on the following topics: Analysis of the protection system in computer distribution and programming systems.