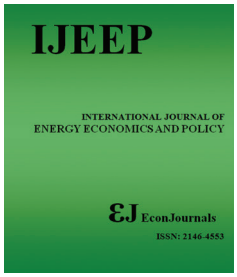

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# The First Auction of Non-Conventional Renewable Energy in Colombia: Results and Perspectives

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**ABSTRACT**

In Colombia, as a historic milestone, the first long-term auction of non-conventional renewable sources was held in 2019, with the aim of the National Government to take a major step in the energy transition policy. The auction organized by the Ministerio de Minas y Energía (MME) defined the objectives, rules and type of auction. The results of the first auction indicate that eight project were selected by a pay-as-bid auction scheme, five wind and three solar projects will imitate operations at 2021accounting for 1298.8 MW. This paper presents a review of auction in various countries of South America in order to compare final prices for technology. Finally, this paper discusses perspectives for the energy sector in Colombia according to the implications of this auction.

**Keywords:** Non-Conventional Renewable Energy, Energy Policy, Auction Mechanism
**JEL Classifications:** O13, Q28, Q42, Q48

## 1. INTRODUCTION

Environmental concerns have led to an increase in investments aimed to reduce conventional fossil fuel-based power generation (Foley and Olabi, 2017; Kasem and Alawin, 2019). As a result, the integration of technologies to produce electricity from renewable resources has been massively pursued worldwide (Ellabban et al., 2014). In recent years, this implementation has been done largely through long-term auctions, which is one of the public policies that has become a global trend (Gutiérrez et al., 2019).

In Colombia, the Ministry of Mines and energy has been formulating different strategies to promote renewable energy (Marín and Villada, 2020; Obregon et al., 2019). The government launched the Renewable Energy Law (Law 1715 of 2014), in order to promote Renewable Energies (RE), demand response and energy management at 2014, this law aims "to promote the development and use of non-conventional energy sources, mainly renewable, in the national energy system, by integrating them into the electric market, non-connected areas and other energy uses" (Congreso de Colombia, 2014). The law establishes the renewable sources as: biomass, ocean, small hydropower, wind, geothermal and solar energy. The Ley 1715 specifically formulates four indirect incentives, all related to tax deductions or exemptions: a 50% income tax reduction, a VAT tax exemption, an import duties exemption and accelerated depreciation (Decree 2143/2015) (Ministerio de Minas y Energía, 2015). Additionally, the government declared an increase of 0.01 USDc/kWh in the electricity tariff designed to subsidize the fund for non-conventional energy and efficient energy management within the RE law (referred by its acronym as FENOGE), which has collected nearly USD $8 million (Ministerio de Minas y Energía, 2015).

During the last decades in Colombia the hydroelectric plants have produced around 65% of the total electricity per year. At today, the total installed capacity is 17,500 MW. The installed capacity

of hydroelectric power stations is approximately 11,000 MW and 5200 MW in thermal plants using coal and natural gas (XM S.A. E.S.P, 2019). In this context, the government of Colombia has decided in 2019 to launch the first auction of renewable energy (RE) with various purposes: to diversify the generation pool, to promote green energy and to ensure energy security (Ministerio de Minas y Energía, 2019c). The auction was leaded by the energy ministry (Ministerio de Minas y Energía [MME]), the planning and regulation offices (Unidad de Planeación Minero-Energética [UPME], and Comisión de Regulación de Energía y Gas [CREG]).

This paper consists of three additional sections. In section 2 is provided a general definition of auction and a detailed review of renewables auctions in Latin America and the Caribbean. Section 3 describes the rules and mechanism of the first non-conventional renewable energy auction in Colombia. At the end of this section, the auction results are analyzed and discussed. Section 4 provides some concluding remarks on this topic.

## 2. LITERATURE REVIEW

An auction is an allocation procedure dependent on an exact assessment rule indicated by the auctioneer and a predefined set of openly accessible guidelines intended to allot or grant articles or items (for example contracts) on the basis of a financial bid (Krishna, 2009). The arrangement of rules determined by the auctioneer are known by the bidders before the auction. An auction may be described by three key standards: bidding, clearing and pricing (Maurer and Barroso, 2011).

The foremost utilized auctions in electricity markets are either uniform price or pay-as-bid auctions (Milgrom and Milgrom, 2004). For uniform price auctions, the price granted to the triumphant providers is set at the offer price of the foremost costly asset chosen to provide the supply. In contrast, in pay-as-bid auctions, the prices paid to the triumphant providers depend on their real offers, instead of the supplier's offer with the most elevated price chosen to provide the supply. Therefore, pay-as-bid auctions are moreover known as "discriminatory auctions" since they pay winners a distinctive price connected to the particular prices advertised in their offers (Tierney et al., 2008).

Pay-as-bid auctions are utilized to designate expansive classes of resources and commodities (Federico and Rahman, 2003). In these auctions, participants submit composed offers of amounts and prices. Their individual demands are totaled to decide the showcase clearing price. Each bidder wins the sum he inquired for at the clearing price and pays as he bid for all units he won (Wittwer, 2018). This type of auction can be used for the selection of the most efficient electricity generation projects and the formation of competitive market prices for electricity produced by renewable energy facilities (Tasmaganbetov et al., 2020).

### 2.1. Renewable Energy Auctions in Latin America and the Caribbean

Some countries in Latin American have high shares of electricity generation from conventional renewable energy sources (i.e. hydropower), with rapid growth during the last year of installed capacity from onshore wind farms and PV solar plants (Le and Bao, 2020). The growth in installed capacity has come from energy auctions, however there is considerable variation across countries in terms of their auction designs and outcomes (Ferroukhi et al., 2016). This section presents a summary of renewable auctions in various countries of Latin America.

In Argentina, the Ministry of Energy launched a renewable energy bidding program called RenovAr, with the aim of producing 20 percent of Argentina's electricity from renewable sources by 2025 (World Bank, 2018). RenovAr was conceived as an auction in which specific technologies, such as onshore wind, solar photovoltaic, biomass, biogas, small hydro and landfill gas, would participate. The first round of RenovAr was held in October 2016, where 123 bids were submitted with an accumulative total of 6346 MW of which 1108 MW was awarded. A second round was held also in October 2016, awarding an additional of 1282 MW. In 2017 a third round was held, which received 228 offers totalling 9403 MW of capacity awarding 1408 MW. Average prices for the third round were, for wind and solar PV in this round was at USDc 4/kWh, for biomass USDc 10/kWh, biogas USDc 15/kWh, small hydro USDc 9 kWh, and landfill biogas USDc 13/kWh (Ministerio de Energía y Mineria-Subsecretaría de Energías Renovables, 2017). The last auction so far, was held in August 2019, where 259 MW were awarded, with an average price of USDc 6.70/kWh. Of which 96.75 MW corresponded to solar PV, with an average price of USDc 5.76/kWh, 128.7 MW corresponded to wind, with an average price of USDc 5.8 kWh, 8.5 MW corresponded to biomass, with an average price of USDc 10.6 kWh, 12.75 MW corresponded to biogas, with an average price of USDc 15.8 kWh, 5 MW corresponded to landfill biogas, with an average price of USDc 12.95/kWh, and 7.38 MW corresponded to small scale hydroelectric power, with an average price of USDc 10.34/kWh (Gubinelli, 2019).

The Brazilian energy system has an installed generation capacity of approximately 160 GW. In Brazil, auctions of specific technologies have been held since 2007 for small hydroelectric and biomass plants, in 2009 for onshore wind energy, and in 2014 for solar photovoltaic energy (Förster and Amazo, 2016). These auctions are mainly conducted as hybrid auctions, in which bidders first participate in an online downclock auction, followed by a round of sealed pay-per-bid bids. In one of the auctions held in April 2018, more than 20,000 MW of bids were received and 1024 MW were awarded. Of which 806 MW corresponded to solar PV, with an average price of USDc 3.5/kWh, 114 MW corresponded to wind, with an average price of USDc 3.5/kWh, 61.8 MW corresponded to thermal capacity from biomass, with an average price of USDc 3.5/kWh, and 41.6 MW corresponded to small scale hydroelectric power, with an average price of USDc 3.5/kWh (Agência Nacional de Energia Elétrica, 2018). The last auction so far, was held in 2019, where 2979 MW were awarded, with an average price of USDc 4.28/kWh. Of which 530 MW corresponded to solar PV, with an average price of USDc 2.05/kWh, 1040 MW corresponded to wind, with an average price of USDc 2.40/kWh, 229 MW corresponded to biomass, with an average price of USDc 4.57 kWh, 734 MW corresponded to gas, with an average price

of USDc 4.59/kWh, and 445 MW corresponded to hydroelectric power, with an average price of USDc 4.73/kWh (Gubinelli, 2019).

The Chilean energy system has an installed generation capacity of over 20 GW (Ferroukhi et al., 2016). In Chile, auctions are held, in which conventional sources are included, and bids are made for blocks of energy per hour or for quarterly blocks (Kruger et al., 2018). In one of the auctions held in 2017, 20700 GWh/year were bid, of which 2200 GWh/year were awarded. These were distributed in 1700 GWh/year in three hourly blocks which were divided into one block between 23:00 and 08:00, another block between 08:00 and 18:00, and a block between 18:00 and 23:00. The remaining 500 GWh/year were awarded in 3-month seasonal blocks. The lowest bid in this energy auction was 2.15USDc/kWh, with an average price of 3.25USDc/kWh (Bellini, 2017).

The Mexican energy system had an installed generation capacity, by 2013, of over 60 GW, whereof 72% came from fossil fuels (IRENA, SENER, 2015). With this in mind, the Mexican government made some reforms on the energy sector in 2014 (Hochberg and Poudineh, 2018). These reforms led to the planning of renewable energy auctions, of the pay-as-bid type. Three auctions have been held, and the first was in 2016. For the auction held in November 2017, 593 MW were awarded, equivalent to 5493 GWh/year with an average price of USDc 2.05/kWh. Of which 3040 GWh/year corresponded to solar PV, with an average price of USDc 2.2/kWh, and 2453 GWh/year corresponded to wind, with an average price of USDc 1.8/kWh. (Hochberg and Poudineh, 2018).

In Peru, 45.7 TWh were produced by 2014, half of which came from non-renewable energy (del Río, 2017). Therefore, the Peruvian Ministry of Mines and Energy introduced the renewable energy auction program. This program is carried out every 2 years, with the aim of reducing prices, and has managed to contract 5228 MW (IRENA, 2017). For the auction held in 2016 1740 GWh/year were awarded, with an average price of USDc 4.3/kWh. Of which 523 GWh/year corresponded to solar PV, with an average price of USDc 4.8/kWh, 739 GWh/year corresponded to wind, with an average price of USDc 3.7/kWh, 29 GWh/year corresponded to biomass, with an average price of USDc 7.7/kWh, and 449 GWh/year corresponded to hydro, with an average price of USDc 4.4 kWh (Díaz López, 2016).

Taking into account the latest auctions of renewable energy from the Latin American countries mentioned above, the most important results are summarized in Table 1. In order to make a comparison among these auctions, the power in MW was used as a measure of allocation. Because some auctions had a greater number of technologies, it was decided to show only three, which are solar, wind and others. This last one is equivalent to the weighted average of any other technology awarded in a specific auction.

## 3. THE FIRST RENEWABLE ENERGY AUCTION IN COLOMBIA

On October of 2019, the first renewable energy auction was performed in Colombia. Although, an auction was cancelled in february of 2019 by the regulation office (CREG) because it did not accomplish with criteria to satisfy enough competence to ensure a fair auction. The auction objectives from the point of view of energy policy were to strengthen the resilience of the electric power generation matrix to events of climate change through diversification of energy sources. Also to promote competition and increase efficiency in price formation through long-term contracting of new and existing electricity generation projects. Additionally, to mitigate the effects of climate variability and change through the use of the potential and complementarity of available renewable energy resources, which allow managing the risk of attending to the future demand for electricity. Furthermore, to promote sustainable economic development and strengthen regional energy security. Finally, to reduce greenhouse gas emissions from the electricity generation sector in accordance with the commitments made by Colombia at the World Summit on Climate Change in Paris (Ministerio de Minas y Energía, 2019c).

The auction was set up as a two-pronged closed envelope auction, which means both buyers and sellers made bids. The buyers were electricity retailers, whose participation was required and mandatory according to the law 1995 of 2019, in article 296 (Congreso de Colombia, 2019). They should do offers at least by the 8% to 10% of their demand in 2018, in order to promote auction competition (Congreso de Colombia, 2019). They had to meet pre-qualification requirements to participate in the auction which were divided into legal and financial requirements. In the other hand the sellers are supposed to be owners or commercial representatives of generation projects that have met the pre-qualification requirements to participate in the auction according legal, financial and technical requirements. The generation project must be registered in the energy planning office of Colombia UPME at first in order to obtain a favorable connection permission to the network. The project must be >5MW (Ministerio de Minas y Energía, 2019c).

**Table 1: Results of the renewable energy auctions in Latin America**

| Country | | | Argentina | Brazil | Chile | Mexico | Peru |
|---|---|---|---|---|---|---|---|
| Year | | | 2019 | 2019 | 2016-inderdiary block | 2017 | 2016 |
| Technologies | PV | Awared (MW) | 96,75 | 530 | 213 | 347 | 59,7 |
| | | Average price (USDc/kWh) | 5,76 | 2,05 | 3,16 | 2,2 | 4,8 |
| | Wind | Awared (MW) | 128,7 | 1040 | 377 | 280 | 84,3 |
| | | Average price (USDc/kWh) | 5,8 | 2,4 | 3,18 | 1,8 | 3,7 |
| | Others | Awared (MW) | 33,63 | 1408 | * | * | 54,5 |
| | | Average price (USDc/kWh) | 12,87 | 4,63 | * | * | 4,6 |
| Overall | | Awared (MW) | 259 | 2979 | 590 | 627 | 198,5 |
| | | Average price (USDc/kWh) | 6,7 | 4,28 | 3,17 | 2,05 | 4,3 |

After the pre-qualification process, both buyers and sellers were able to submit their bids, which had to meet certain conditions. In the case of the buyers' bids, the conditions were that they may submit one or more bids. Each bid presented by the buyer shall be understood for a period of 24 h. The offer must indicate the maximum amount of energy to buy in a day in megawatt hour (MWh-day) and the price at which were willing to buy in Colombian pesos per kilowatt hour (COP $/kWh), not including the CERE (Actual Energy Equivalent Cost). The bid price of the buyer shall be understood as the weighted average price per kilowatt hour (COP $/kWh) that he is willing to pay for all the contracts assigned to him for each offer. The sum of the quantities of all offers may not exceed the average daily commercial demand of the buyer for the prior year (Ministerio de Minas y Energía, 2019d).

In the case of the sellers' bids, the conditions were that they may submit one or more bids for each intraday block, which are divided in one block between 00:00 and 07:00, other block between 07:00 and 17:00, and a block between 17:00 p.m. and 24:00. Each offer must indicate the amount of energy packages (0.5 MW) to be sold for each intraday block and the corresponding price, not including the CERE. For each bid the seller may indicate the maximum and minimum number of energy packages that he is willing to accept for the same offer price. The amount of energy of the total offers that can potentially be awarded cannot exceed the average daily energy of the generation project. The seller must indicate for each offer whether or not to present one of the restrictions, which are simultaneous, excluded or dependent (Ministerio de Minas y Energía, 2019d).

## 4. AUCTION MECHANISM: PAY-AS-BID MODEL

The auction was awarded through a methodology seek the combination of offers that maximizes the consumer's benefit, proposed by the planning and regulation offices (Unidad de Planeación Minero-Energética (UPME). Nevertheless, the weighted average price of all contracts awarded in the three intraday blocks could not exceed the average maximum limit. Before starting the adjudication process, the sales offers that exceed the maximum individual top were not included and the simultaneous and dependent sales offers related to those offers. The objective function is defined as the maximization of the consumer's benefit, as can be seen in Eq (1).

### 4.1. Indices

G=Set of generation projects that make an offer to sell.
C=Set of marketers making purchase offers.
B=Set of intraday demand blocks.
OC=Set of purchase offers.
OV=Set of sale bids.
Idc=Code with name of the marketer c and a daily energy quantity in MWh-day.
Idv=Code with name of generator g, a block b and a maximum and minimum quantity of packages.

### 4.2. Parameters

PTP=Average top price ($/kWh).
PTS=Peak price ($/kWh).
TP=Package size in (MWh).
$PV_{Idv}$=Sales price of sales bid ID Idv ($/kWh).
$MXG_{Idv}$=Maximum number of packages of the sale offer ID Idv (packages).
$MNG_{Idv}$=Minimum number of packages of the Sales Offer ID Idv (packages).
$PC_{Idc}$=Purchase price of purchase bid ID Idc ($/kWh).
$MXC_c$=Maximum energy that trader C is willing to buy for the whole day (MWh-day).
$D_B$=Duration in hours of block B.
$FP_G$=Plant factor defined by the UPME for the project technology G.

### 4.3. Variables

AsV=Positive integer variable representing the assigned power of the sale bid (kWh-block)
AsC=Positive integer variable representing the assigned energy.

### 4.4. Objective Function

$$\max\left[\sum_{c\in OC} PC_c \cdot AsC_c - \sum_{v\in OV} PV_v \cdot AsV_v\right] \quad (1)$$

### 4.5. Restrictions

1) Restriction of balance between purchase and sale allocations

$$\sum_{c\in OC} AsC_c = \sum_{v\in OV} AsV_v \quad (2)$$

2) Restriction to control maximum purchase offers

$$\sum_{c\in OC} AsC_{Idc} \le MXC_{Idc} \quad (3)$$

3) Restriction to control maximum and minimum sales bids

$$MNG_{Idv} \cdot D_B \cdot (0.5) \le AsV_{Idv} \le MXG_{Idv} \cdot D_B \cdot (0.5) \quad (4)$$

4) Restriction to guarantee a bid price from buyers lower than the weighted sales price of the daily allocation

$$PC_c \le \frac{\sum_{v\in OV} PV_v \cdot AsV_v}{\sum_{v\in OV} AsV_v} \quad (5)$$

5) Restriction to ensure that the weighted sales allocation price is lower than the average ceiling price

$$\frac{\sum_{v\in OV} PV_v \cdot AsV_v}{\sum_{v\in OV} AsV_v} \le PTP \quad (6)$$

6) Restriction to exclude sales bids higher than the upper limit price

$$PV_{Idv} \le PTS \quad (7)$$

7) Control of dependent, exclusionary and simultaneous sales offers

## 5. RESULTS

As an initial process, there were a total of 68 companies that could potentially be participants. From these, 53 companies submitted envelope, of which 26 were retailers and 27 generators with 56 projects (Ministerio de Minas y Energía, 2019a). Among the bidders were the Spanish companies Acciona, Solarpack and Cobra, the Chinese manufacturers Trina Solar, the Canadian company Canadian Solar, the French companies EDF and Greenyellow and the Italian company Enel, as well as several Colombian generators. Among the buyers were the Colombian renewable energy company Celsia, the oil company Empresa Colombiana de Petróleos (Ecopetrol) and Enertotal.

The projects that were selected at the auction had a 15-year power purchase agreement (PPA) and the generation assets must be operational by January 01, 2022. The contracts are linked to the Colombian currency and will be updated annually according to a Producer Price Index certified by the National Administrative Department of Statistics of Colombia (Ministerio de Minas y Energía, 2019d). The demand determined by the MME was 12,050.5 MWh-day. The individual maximum limit and the average maximum limit established by the Energy and Gas Regulation Commission was COP 200/kWh or USDc 5.83/kWh and COP 160/kWh or USDc 4.67/kWh, respectively (Ministerio de Minas y Energía, 2019a).

As a result of this mechanism, generation responsibilities were assigned to eight awarded projects with a total effective capacity of 1298.8 MW of installed capacity. Five of them are large wind projects with a total capacity of 1073 MW and three large solar projects with a total capacity of 225.8 MW (Ministerio de Minas y Energía, 2019a). The allocation had a weighted average price of COP 95.65 /kWh or USDc 2.79/kWh (Ministerio de Minas y Energía, 2019a). A total assigned energy of 10,186 MWh-day was obtained, divided as follows: 2754.5 MWh-day corresponding to Block 1, 6906.5 MWh-day corresponding to Block 2 and 525 MWh-day corresponding to Block 3. These correspond to 393.5 MW of wind power in Block 1, 513.5 MW of wind power and 177.15 MW of photovoltaic power in Block 2, and 75 MW of wind power in Block 3 (Unidad de Planeación Minero Energética (UPME), 2019). These results can be seen in Figure 1 and are shown in detail in Table 2.

The development of wind farms will be developed by AES Colombia with Casa Eléctrica; Energía de Portugal with Vientos del Norte (also known as Alpha); Energía de Portugal with Eolos (also known as Beta); Celsia (through Epsa with Acacia 2); and Celsia (through Epsa with Camelia 2). The development of the three photovoltaic farms will be developed by Trina Solar (Campano, Cartago and San Felipe complexes).

Trina Solar is a company from China whom manufacture solar panels, the capex of Trina could be between US $ 0.50 and US $ 0.60 million per megawatt (MW) (Bellini, 2019). The three project (Campano, Cartago and San Felipe) are located near the municipality of Puerto Gaitán (Meta), and together will have an installed capacity of 360 MW (Bellini, 2019).

Other company that were protagonists in the auction were Electricidad de Portugal and its subsidiary Electricidad de Portugal Renewable, were assigned two wind generation contracts that represent a total installed capacity of 500 MW. The contracts that it develops with the Portuguese Renovatio, contemplate the energy that will be produced by two wind farms. Winds of the North-Alpha, with a capacity of 212 MW, and Eolos Energía-Beta, of

**Figure 1:** Power allocated in each inter-day block

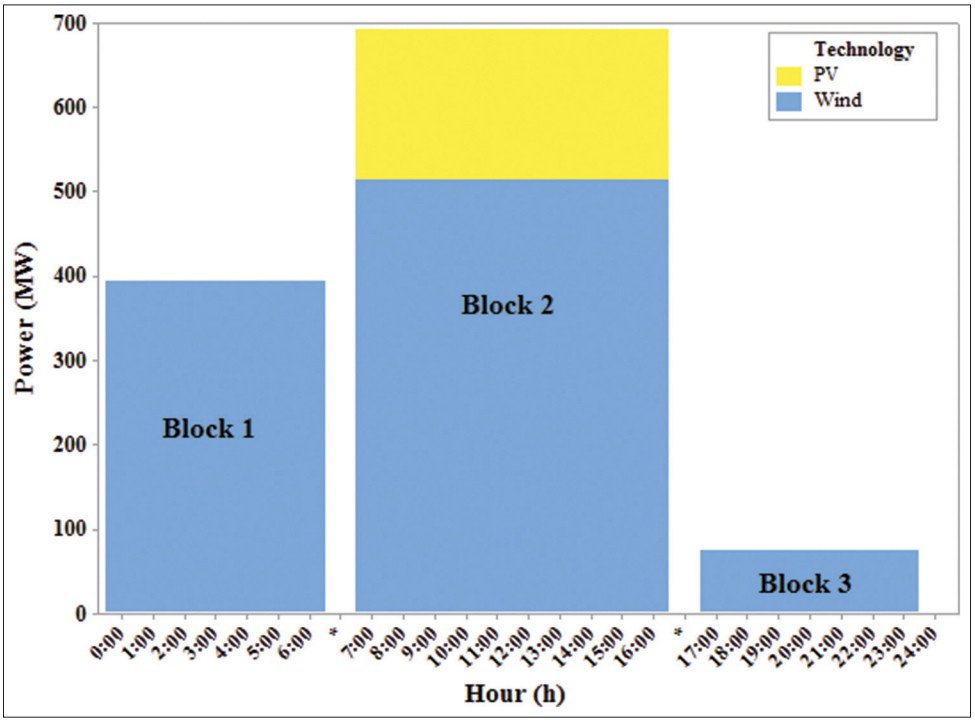


**Table 2: Results of the Colombian renewable energy auction**

| Companies | Projects | | B1 | B2 | B3 |
|---|---|---|---|---|---|
| ELECTRICIDAD DE PORTUGAL | ALPHA | Awared (MW) | 98,00 | 116,50 | 27,00 |
| | | Price (USDc/kWh) | 2,58 | 2,58 | 2,58 |
| | BETA | Awared (MW) | 126,00 | 151,50 | 33,00 |
| | | Price (USDc/kWh) | 2,74 | 2,74 | 2,74 |
| EMPRESA DE ENERGÍA DEL PACIFICO S.A. E.S.P. | Eólico Acacia 2 | Awared (MW) | 11,50 | 11,50 | 11,50 |
| | | Price (USDc/kWh) | 2,97 | 2,97 | 2,97 |
| | Eólico Camelia | Awared (MW) | 3,50 | 96,00 | 3,50 |
| | | Price (USDc/kWh) | 3,03 | 3,03 | 3,03 |
| JEMEIWAA KA´I S.A.S. E.S.P | Casa Eléctrica de 180 MW | Awared (MW) | 154,50 | 138,00 | 0,00 |
| | | Price (USDc/kWh) | 2,86 | 2,86 | 0,00 |
| TRINA SOLAR | CARTAGO 99 MW | Awared (MW) | 0,00 | 61,50 | 0,00 |
| | | Price (USDc/kWh) | 0,00 | 2,74 | 0,00 |
| | SAN FELIPE 90 MW | Awared (MW) | 0,00 | 56,00 | 0,00 |
| | | Price (USDc/kWh) | 0,00 | 2,89 | 0,00 |
| | EL CAMPANO | Awared (MW) | 0,00 | 59,65 | 0,00 |
| | | Price (USDc/kWh) | 0,00 | 2,91 | 0,00 |
| OVERALL | | Awared (MW) | 393,50 | 690,65 | 75,00 |
| | | Price (USDc/kWh) | 2,76 | 2,81 | 2,73 |

280 MW, whose commercial exploitation is planned for 2022. The prices established for dispatch are between $ 87,000 and $ 92,000 per megawatt hour (MW/h).

Another of the protagonists of the aforementioned auction was AES Colombia, with the Jemeiwaa Kai wind complex, which is made up of five parks, and an installed capacity of 648 MW and located in Uribia (Guajira). The projects are: Irraipa (99 MW), Carrizal (195 MW), Apotolorru (75 MW), Jotomana (99MW) and Casa Eléctrica (180 MW) projects, only the last one was awarded in this auction.

The Celsia (utility at Colombia) was also a relevant player in the auction, two of its Acacia 2 (80 MW) and Camelia 2 (250 MW) wind projects, also located in La Guajira, and which it develops with the Renovatio company, together they have an installed capacity of 330 MW. It draws the attention of the auction that Enel Green Power, an important utility in Colombia did not get winners projects.

Once the awarding process was completed, UPME verified that there was a positive difference between the target demand and the amount of energy allocated in the auction, this difference was 1864.5 MWh-day, therefore, the complementary mechanism was activated.

Through this mechanism, 1864.5 MWh-days were awarded, with a weighted average price of COP 106.65/kWh or USDc 3.11 kWh. Three generation projects were assigned, of which two were also awarded in the previous process (Campano and Acacia 2), and the third is the Apotolorru project with 75 MW of installed capacity, which is part of Jemeiwaa Kai wind complex. The three projects were distributed 1.26% corresponds to solar photovoltaic and 98.74% to wind, in terms of energy (Ministerio de Minas y Energía, 2019b).

## 5.1. Analysis

The results showed that both national and international investors in renewable energy established Colombia as an attractive country for this type of projects. The auction was able to seize similarly favorable global market conditions and repeat the successes seen in Chile, Argentina, Peru, Brazil and Mexico. Even taking into account the terms of the auction contracts in Colombia are for 15 years, in contrast with Chile, Argentina and Mexico, contract terms have been 20 years, which is also standard for large-scale renewable energy contracts worldwide.

Although it seemed that the first auction and the conditions in Colombia added a monetary risk, which could discourage many investors, the results showed the opposite. This is because the prices of solar and wind equipment have decreased, giving investors greater coverage. This generated successful bids at a maximum price of 110, with a weighted average price for 10,250 MWh-day of USDc 2.79/kWh, and with the complementary mechanism a weighted average price of 100.65. For 1080 MWh-day. In other words, for the first auction held in Colombia, 12,500 MWh-day were awarded at a weighted average price of USDc 2.87/kWh.

Compared to the results of the last renewable energy auctions held in different Latin American countries (Figure 2), the final weighted price of the auction is the second lowest, only above the 2.05 awarded in Mexico in 2017, which was a historical result. It is important to mention that the auctions held in other Latin American countries, were awarded projects of technologies other than solar and wind, such as biomass, biogas and small-scale hydropower.

The variations among prices awarded at auctions in recent years in Latin America are given by the geographical, climatological, economic, technical, social and political aspects of each country. In addition, as new auctions are designed and implemented, these mechanisms change in order to generate the required energy allocation, lower prices and improve competition in the energy market. Among the most important elements that auctions of this type have had in recent years are longer contract durations, more time for project implementation, the use of inter-day blocks, and the exclusivity for certain technologies and better guarantees for both buyers and sellers.

**Figure 2:** Price comparison between the last Latin American auctions

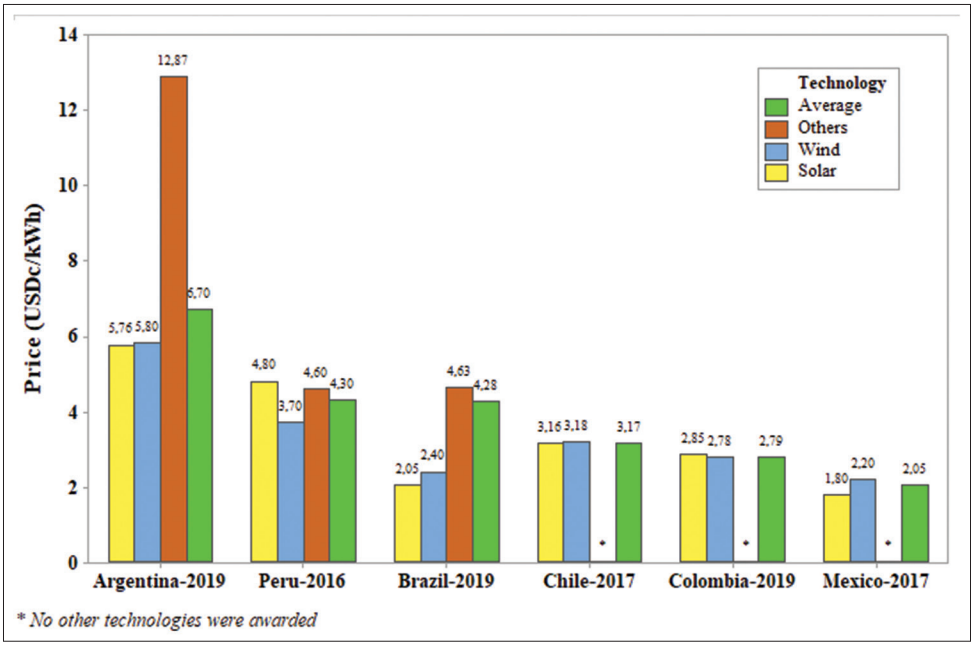
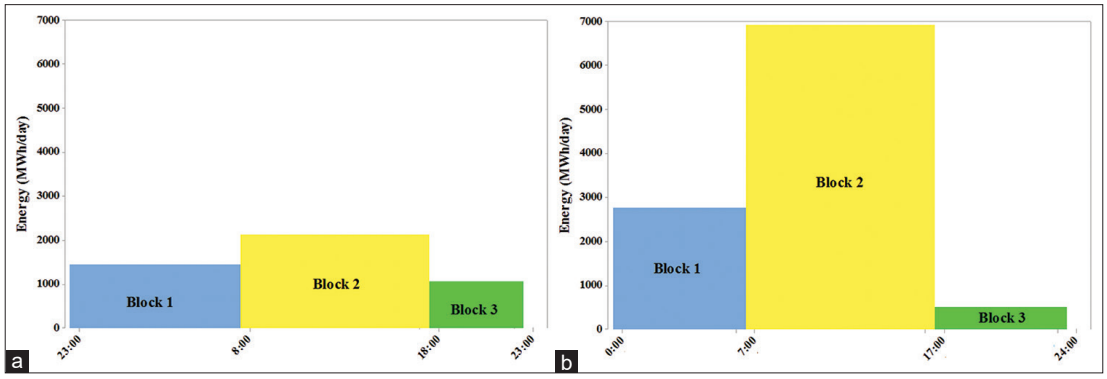



**Figure 3:** Energy awarded in the auction with inter-daily blocks, Chile (a), and Colombia (b)




One of the mechanisms used in the Colombian auction, which generated these historical results, was the condition that the sellers could auction in three intraday blocks. This meant that the sellers could evaluate their resource and make bids that would give them more profit, without being obliged to make these bids for the whole day. A clear example is the photovoltaic system projects, where the sellers only auctioned in the intraday block 2, which had the hours of photovoltaic production. This mechanism has been used in other auctions around the world, such as Chile's auction in 2017, which also had three intraday blocks, however the hours of the blocks and the distribution of energy in these, varies with respect to that of Colombia, as can be seen in Figure 3, due to the geographical location and hours of higher demand for electricity in each country.

## 6. CONCLUSIONS

The transition of the world's energy sources from fossil fuels to renewable energy to prepare the roadmap for a zero-carbon future is a reality. However, most current electricity market policies have serious shortcomings in terms of the potential for mass deployment of these energies. In this context, auctions have become one of the most effective instruments to speed up the implementation of renewable energies and at the same time promote price competitiveness.

The success of the first auction of non-conventional renewable energy in Colombia has been largely due to public policy. Regarding the generators, the policies that stand out the most are the use of 3 blocks/day, 15 years of contracts and the exclusive participation of non-conventional renewable energy sources. From the point of view of the retailers, the main factor was the direct intervention brought about by the complementary allocation mechanism proposed by the MME.

The results of the auction show that Colombia is a country that generates high interest in renewable energy investment. Furthermore, these technologies can compete in price with conventional energy sources in the Colombian context. In addition, these results can generate a greater interest in national and international investment in this type of technology, accelerating the massive implementation of renewable energy in the Colombian territory.

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