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Article

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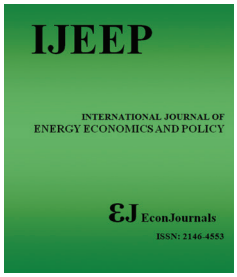
Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

Reference: Moreno, Ricardo/Cantillo, Sergio A. et. al. (2021). Risk analysis of firm energy coverage in Colombia in the medium term. In: International Journal of Energy Economics and Policy 11 (2), S. 220 - 226. https://www.econjournals.com/index.php/ijeep/article/download/10490/5724. doi:10.32479/ijeep.10490.



International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2021, 11(2), 220-226.

Risk Analysis of Firm Energy Coverage in Colombia in the Medium Term

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Received: 20 August 2020 **Accepted:** 10 December 2020 **DOI:** https://doi.org/10.32479/ijeep.10490

ABSTRACT

The recent auction of firm energy and the decisions on medium-term coverage give rise to risks in the supply of electricity in Colombia in the coming periods. Taking into account the possible risks that may arise, such as: non-compliance with FEO due to generation units (six [6] non-compliances during 2015-2016 term), the delay of generation projects with committed firm energy (Hidroituango case) and the availability of firm energy in the market, imply a systemic risk for the electric power supply in the medium term. Through the study of technical documents and resolutions, issued by the CREG, about the medium term energy balances in 2018, firm energy supply and demand balances were reconstructed, including the results of the last FEO auction carried out in the first quarter of 2019, in order to carry out a risk analysis based on these same scenarios. It was observed that the amount of FEO auctioned exceeds the quantity of demand projected, meaning that the CREG assumed a conservative position by purchasing more energy than necessary (8650 GWh-year and 1027 GWh-year respectively), this is a situation that has occurred on more than one occasion.

Keywords: Reliability Charge, Firm Energy, Firm Energy Obligation, Risk
JEL Classifications: L78, L94, Q41, Q42, Q48

1. INTRODUCTION

Installed capacity to produce electrical energy in Colombia is constitute by hydraulic generation plants that correspond to 70% of the total, thermal generation plants in their different technologies: coal (10%), natural gas (11%) and liquid fuels (9%), and non-conventional energy sources (1%) (UPME, 2018; García-Rendón and Pérez-Libreros, 2019). With regard to energy coverage in the National Interconnected System, in the medium and long term, given the high vulnerability to climate change of producing electricity with this type of energy in (Olaya et al., 2016; Pupo-Roncallo, 2019), the energy and gas regulation commission (CREG) established in December 2006, by means of Resolution 071 of 2006, the methodology for the assignment and remuneration of the reliability charge (CxC), which has the objective to guarantee, at all times, a reliable energy supply at efficient prices, meeting the demand when water resources are critically scarce in periods of drought (CREG, 2006a; ACOLGEN, 2019). This mechanism aims to promote the expansion of the generation park, in principle efficiently, in the long term through auctions or other allocation mechanisms, when the CREG identifies a firm energy deficit in the medium or long term (CREG, 2018a; CREG, 2018c).

In principle, new generation projects and existing units of both conventional and non-conventional technologies can access the reliability charge through firm power auctions and therefore, commit firm power obligations (FSOs) (CREG, 2006a; Harbord, 2016), which correspond to the commitment that generators acquire to produce an amount of energy according to the ENFICC in critical supply conditions; covered by generation assets that are in the capacity to produce under these circumstances (CREG, 2018a). The generator to which a FEO is assigned is committed to

deliver the agreed amount of energy when the stock market price at least in 1 h exceeds the cap established by the CREG, called the shortage price (Bedoya et al., 2016; Gonzalez-Castellanos et al, 2018).

During the normal period between firm energy auctions, other allocation mechanisms can be carried out, given that, as mentioned in (CREG, 2006a), *"during the first semester of each year, the CREG will verify if the sum of the ENFICC for each generation unit is equal to the target demand calculated for the term beginning on December 1, in accordance with the provisions of article 19 of this resolution."* This verification process is carried out by means of balances of ENFICC and target demand. However, since the entrance of the Reliability Charge mechanism in 2008, and the auctions of the following years, the allocation mechanism and its validity was put to the test during the great period of rainfall shortage caused by the El Niño Phenomenon, that occurred between 2015 and 2016 (McRae and Wolak, 2019). Recent CREG reports indicated that during this event, financial guarantees were made effective to six (6) hydraulic plants for non-compliance with firm energy commitments. In this way, the effectiveness (avoiding risk of shortages) of the execution of the financial guarantees depends on the availability of energy in the market. In this sense, the CREG commissioners realized that the energy balance, based on which the calls and subsequent allocations of FEOs are made, must explicitly incorporate the risk of including firm energy bids from hydroelectric plants in the auction.

Therefore, through the CREG 115 document of 2016, it is proposed that the annual firm energy balance should discriminate from the total firm energy, that energy which is committed by the agents of hydroelectric power plants. In other words, firm energy, but associated with a risk of default on as already observed during the 2015-2016 period. In this way, calculating the firm energy that can be guaranteed by hydropower plants under low hydrological conditions may represent a risk, given the intrinsic contradictions involved in calculating firm energy from hydropower plants that exploit a scarce resource under drought conditions. This condition suggests constant study and monitoring by both researchers and monitoring entities.

This article provides an analysis inspired by the technical document D-050, presented by the CREG in 2018, where three scenarios were proposed based on different operating conditions of the generation units that have FEOs in place, given the high probability of the appearance of the El Niño phenomenon in the next 4 years from the publication of the document. These scenarios include information corresponding to the new FEO allocations made through an auction held in February 2019, describing the respective effect.

The article is structured as follows: Chapter 2 provides a context of the implications of firm energy calculation for the different technologies for the reliability charge and the motivations that induced CREG to hold an auction to allocate new FTOs for the 2022-2023 period. The methodology used to propose scenarios and analyze the information is contained in chapter 3. Chapter 4 presents the results and the respective analysis of the proposed scenarios. Finally, chapter 5 presents the conclusions of the article.

2. PROBLEM FORMULATION

In reliability charge auctions, the auctioned market product is firm energy, called ENFICC (Firm Energy for Reliability Charge), which is defined in (CREG, 2006a) as *"the maximum amount of electrical energy that a generation unit is capable of delivering continuously under low hydrologic conditions, over a period of 1 year."* The methodology to calculate or determine firm energy is defined by CREG according to the methodology presented in Resolution 071 of 2006. According to annex 3 of this resolution, the calculation of the ENFICC for thermal power plants depends on the capacity of the plant, the availability of fuel(s) through the supply contracts and unavailability index of forced outputs, among other parameters according to fuel and technology.

On the other hand, the calculation of the ENFICC for hydroelectric plants is done through a mixed integer linear programming optimization model (MILP) whose complete formulation is found in annex 9 of Resolution 071 of 2006. The objective of the optimization problem is to maximize the capacity to generate electric energy for each generation plant for all years with historical records of monthly water flows. In this way, the FE calculation is based on historical records, including the chronological order of each of the series, that is, there is a replica of the hydrological events (both drought and high rainfall) (Osorno-Cardona et al., 2018).

The second step in the methodology for calculating the FE of hydroelectric power plants consists of organizing the annual historical FE values from lowest to highest and thus constructing a probability distribution curve for each unit, expressed in kilowatt hours per day per year (kWh-day/year). The lowest value corresponds to the 100% probability of available energy surplus and is identified as the base ENFICC, which according to (CREG, 2006b) "*corresponds to that generation that is capable of delivering a plant in the condition of 100% PSS*" (PSS: probability of being exceeded). The base ENFICC is used in the firm energy auctions for the reliability charge as the reference value in the firm energy declaration. If the agent representing a hydropower plant chooses to offer a higher energy value than the base ENFICC, then it must back up this difference with a guarantee.

From the probability distribution, a key value is obtained in the estimate of the FE, corresponding to the 95% PSS ENFICC, that according to the resolution CREG 079 of 2006, "*corresponds to that generation that is capable of delivering the plant in the condition of 95% PSS of the probability distribution curve*" (CREG, 2007). In firm energy auctions for the reliability charge, the agent can make bids between the base ENFICC and the 95% ENFICC. This 5% bidding margin represents a risk indicator since the base ENFICC assumes that historical low-hydrological events will be replicated in the medium and long term and this level represents the minimum bid value.

In this context, in 2018, the CREG published Res. 104 of 2018, which provides for the holding of an auction to assign the FEOs

of the Reliability Charge for the period from December 1, 2022 to November 30, 2023. This resolution follows the recommendations of CREG Documents 050 and 075 of 2018 and the draft Resolution CREG 064 of 2018, regarding the requirement to convene an auction for the entry of new generation projects for the period 2022-2023, given that projections indicate a deficit in firm energy for the period 2022-2023, as shown in Figure 1.

About risk analysis, Resolution 104 CREG of 2018 points out some key aspects detected during the El Niño Phenomenon 2015-2016 that highlight the risk in energy coverage in the medium term. The CREG finds "*convenient that in the annual firm energy balance sheet, the portion corresponding to the incremental ENFICC to be discriminated from the total firm energy*" (CREG, 2018b).

The incremental ENFICC corresponds to the agent's supply from each plant that is greater than the base ENFICC and is backed by a financial guarantee that is activated in the event of default and which, in principle, would allow the missing energy to be purchased from another agent. In this sense, the document emphasizes about: "*the need to reassess the concept or parameterization of the incremental ENFICC, particularly in a scenario of a more restricted power supply, where the financial guarantees are insufficient to mitigate the risk of default in the event that there is no more physical energy in the system to cover the shortfall*" (CREG, 2018b).

In this sense, and initially in accordance with the evidence and findings, article 7 of that resolution indicates that ENFICC 98% PSS will be used in the auction as the highest bid level for agents representing existing hydraulic generation plants. The allocation of FEOs is done through auctions, which are held with the objective of delivering these obligations among generators and investors that guarantee the reliability of long-term energy supply at efficient prices (CREG, 2006a). These auctions are normally held between 3 and 4 years before the agreed firm energy is required, that was the case until 2012 (Cramton, 2015). In this case, it occurs because of the described shortage condition.

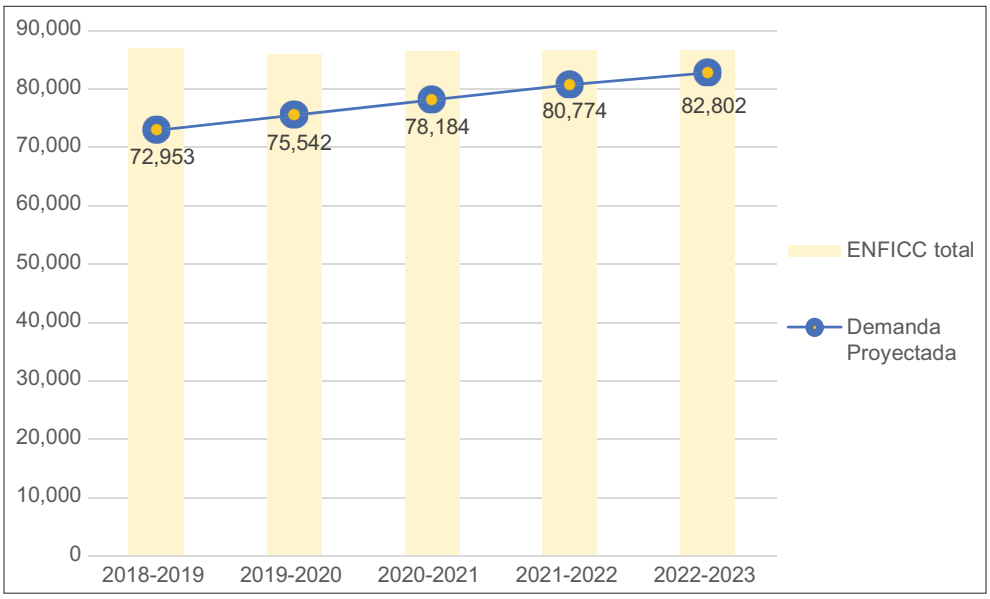
In FEO auctions can participate generation agents that already deliver energy to the system and investors in new projects of this type, that meet the requirements of both financial and environmental guarantees of operation to deliver this energy, as well as the declaration of parameters and firm energy in the stipulated times, where those agents or investors whose reserve prices are lower than the closing price of the auction will be winners of these auctions, in order to guarantee efficient energy resources.

3. METHODOLOGY

According to the verification, CREG has allocation mechanisms to perform annual verifications, if the comparison shows a deficit (less supply of ENFICCs than demand) an allocation is called by auction, encouraging the entry of new plants (for those plants FEOs are allocated for up to 20 years [CREG, 2018b]). On the other hand, if there is a surplus (more supply than demand), a managed allocation is made (CREG, 2018a) for a period of 1 year among existing units on a "pro-rata" basis of their share of total supply, without the inclusion of new plants (CREG, 2018b).

The CREG, at the end of the 2018-2019 period, considered it appropriate to determine the mechanism for allocating FEO for four periods, i.e., 2019-2020, 2020-2021, 2021-2022 and 2022-2023. For the first three periods through resolution 065 of 2018, it made the allocation through the mechanism of managed allocation, however, the balances made in (CREG, 2018a) show that the firm energy available was still sufficient to meet the demand, but recommended the incentive to the entry of projects in the effect of 2021-2022, given the uncertainty of entry of the Ituango project. Similarly, for the period 2022-2023, the technical document recommended holding an auction for the allocation of FEO, as there was a deficit in meeting the demand (CREG, 2018b).

Figure 1: Demand projections versus ENFICC totals



The analyses carried out by (CREG, 2018a) firstly, pointed to a re-evaluation of the participation of the incremental firm energy of the hydroelectric plants in the FEO allocations, taking into account the little margin that the system would have to solve failures during critical periods, making necessary the reduction of the risk that the agents can assume. During the 2015-2016 El Niño phenomenon, a third of the incremental ENFICC could not be delivered to the system, an amount of energy that cannot be neglected, especially during critical periods, and, secondly, CREG identified possible delays in generation projects that were to come into operation in 2018 and that had FEO from auctions held previously, such as the cases of Hidroituango and Termonorte.

Thanks to the analysis and conclusions mentioned above, CREG decided that, by the first quarter of 2019, a reconfiguration auction should be held for the period 2022-2023 (CREG, 2018c), in order to meet the growing demand and mitigate all the risks described above. However, the Colombian electricity sector is characterized by three aspects: (a) being highly regulated, (b) centralized planning and (c) vertically integrated, therefore, firm energy auctions commonly reflect a conservative stance that tends towards excessive security, thus shifting the investment costs of additional resources directly to consumers (Buriticá-Arboleda et al., 2019).

Thus, through the system operator's platform (XM), the FEO results assigned for the four (4) terms described were extracted, including those assigned in the auction held in the first quarter of 2019 for the term 2022-2023. From this information, the scenarios presented in (CREG, 2018a) were reconstructed as firm energy supply and demand balances (that is, FEO defaults by water generation units, as well as delays in generation projects such as Hidroituango and Termonorte), whose results were analyzed according to what each scenario initially proposed, as well as the impact of the auction held under said circumstance. The detail of each scenario as well as its respective analysis is found in the results section.

4. RESULTS AND DISCUSSION

Firstly, the information resulting from the auction in the first quarter of 2019 highlights the inclusion of FEOs from renewable energy sources such as wind power plant projects and solar panels, with a low percentage of participation (1%). However, the inclusion of this type of energy is a starting point for further analysis regarding trends, applicable policies, characteristics, and scenarios for the medium and long term planning and operation of the Colombian electricity sector regarding these resources, such as the studies carried out by Paez et al. (2017), Barrientos and Villada (2020), Cabello et al. (2019), Obregon et al. (2019) and Forero et al. (2019), Castro et al. (2019) among others. On the other hand, this result also reflects the effect of the incentives derived from the application of Law 1715 in Colombia, referring to the inclusion of RE in terms of environmental sustainability and resilience of the sector to adverse weather conditions (Arias-Gaviria et al., 2019).

In the same way, there was a strong reduction in the RE from water generation units (9.67%) and the increase of RE for most of the thermal generation technologies (i.e., gas and liquid fuels) with respect to the existing firm energy obligations before the auction, as shown in Figure 2.

In order to visualize the impact of the CREG's position on the risk of shortage, two (2) scenarios were created to reconstruct those proposed by the CREG in its official technical document (CREG, 2018a), including the FEOs auctioned for the 2022-2023 term in the first quarter of 2019. The description and results of the scenarios are set out in the following subsections.

For a better understanding of the results of the proposed scenarios, two (2) additional concepts should be considered: the incremental executed guarantee ENFICC, which refers to firm energy that cannot be delivered by one or more generating units, with the activation of the respective economic guarantees, and on the other hand, the incremental non-executed guarantee ENFICC, which is considered the incremental firm energy that can be delivered in critical periods by the generating units without any inconvenience.

4.1. Non-compliance of FEO from Hydropower Plants

In the first scenario, as mentioned in the CREG document, it is proposed that an amount of firm committed energy equivalent to the greatest historical non-compliance of FEO presented (i.e., 33.3% of FEO during El Niño phenomenon of 2015-2016) that comes from water generating units, given the vulnerability of the resource, cannot be delivered during an eventual period of extensive drought, activating the condition of scarcity price. This information was contrasted with the demand forecast for each of the periods under study.

This scenario was considered to verify the effects of the auctioned FEO in mitigating the impacts of non-compliance of said generating units, which were evidenced in the CREG technical document. The results are shown in the supply and demand balance of FE presented in Figure 3.

The supply-demand balance for this scenario shows that for the 2022-2023 period, the amount of firm energy acquired is sufficient to supply the demand projection without resorting to the available incremental ENFICC, showing the mitigation effect of the new FEOs included in that period. On the other hand, the incremental ENFICC of the 2022-2023 period show a lower amount of incremental energy compared to the other periods under study that were not adjusted and were assigned from a previous FEO assignment, which shows a positive effect on the resilience of the electricity sector to climate change.

However, there is a surplus of firm energy (FE) for this same period, given that the difference between the total FEOs and the demand projection shows a surplus FE of 8650 GWh-year, equivalent to the amount of firm energy that the largest generating plant in the country (Ituango) could offer. This means that, under this scenario, CREG will have to go out to the market to resell this large amount of FE surplus to interested agents not necessarily at the price it acquired them, which could represent higher costs to the end user, where the conservative stance assumed by CREG in this regard is evident.

Figure 2: ENFICC 2022-2023 versus new reconfiguration auction results for the 2022-2023

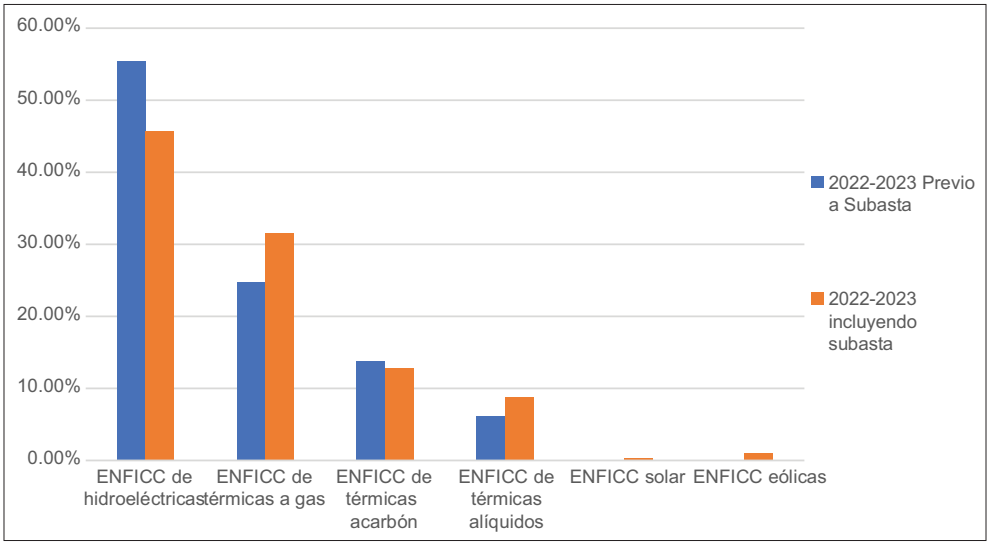
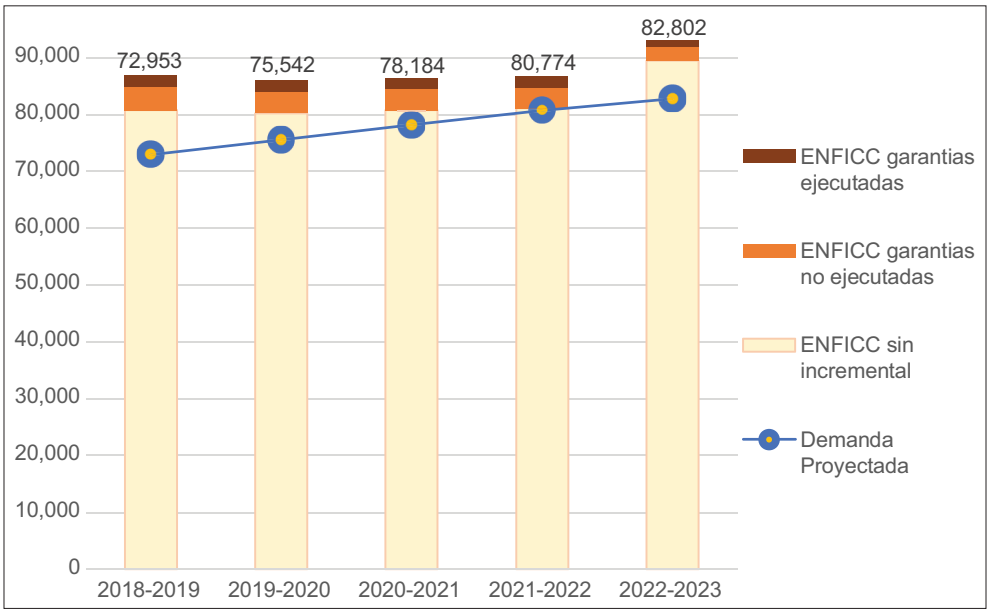


Figure 3: Supply and demand balance of firm energy - default scenario, including those allocated at auction in 2019



On the other hand, it can be seen that for the 2021-2022 term, the demand projection matches with the amount of ENFICC without including the incremental one, which suggests that, under any contingency of any of the generation units with FEO for that term, it would represent a great risk of shortage, having to resort to the incremental ones or go to the market to buy this missing energy.

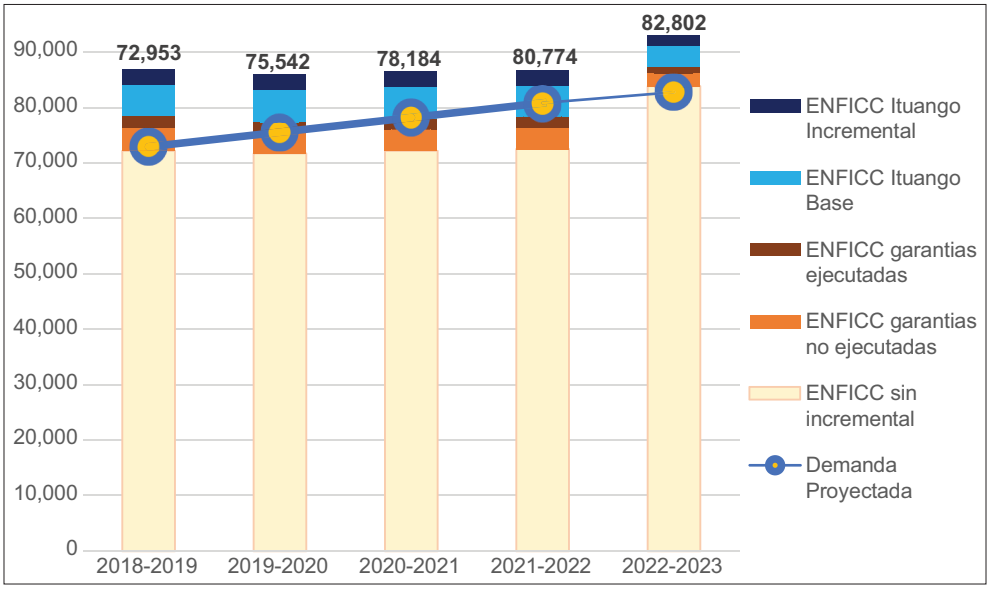
4.2. Delay in Generation Projects

The second scenario refers to the delays that the new generation projects acquired by FEO in the period under study would present. In this particular case, as the CREG document explicitly refers to the cases of Hidroituango (8529 GWh-year including incremental ENFICC) and Termonorte (619 GWh-year), this is due to the fact that recent audit reports have shown delays of more than 8 months in some cases, and the high probability of further delays and inconveniences for the implementation of these projects. As in the previous scenario, this information was contrasted with the demand forecast for each of the periods under study.

This scenario was developed to determine the effects of these delays, especially that presented by Hidroituango on the medium-term energy reliability of the SIN, given that firm energy committed by this plant represents a large percentage of the FEOs in the period under study, as evidenced in the CREG document. The effects of the auctioned FEOs on mitigating the aforementioned impacts will also be determined. The results of this scenario are shown in the corresponding FE supply and demand balance presented in Figure 4.

The supply-demand balance for this scenario shows that, for the period 2022-2023, the amount of firm energy acquired is enough to supply the demand projection under these circumstances without resorting to the available incremental ENFICCs, which effectively shows that the FEOs allocated in the auction can amortize the negative effects of the proposed scenarios. As in the previous scenario, the incremental ENFICCs for the 2022-2023 period show a lower amount of incremental, making evident the case

Figure 4: Supply-demand firm energy balance – delay generation projects scenario, including those allocated in the 2019 auction



of Hidroituango (base and incremental ENFICC) with respect to other periods under study that were not adjusted and were allocated from a previous FEO allocation.

However, the firm energy surplus (FE) presented for the same term is much lower in comparison to the previous scenario, given that the difference between the total FEOs and the demand projection shows a FE surplus of 1027 GWh-year. This means that, under this scenario, CREG will also have to go out to the market to resell this amount of FE surplus to interested agents, not necessarily at the price it acquired them, which could represent a higher costs to the end user, although these costs will be comparatively lower than those that could be presented in the previous scenario. This fact confirms the effect of the conservative position taken by the CREG, given that under these circumstances there are still FE surplus.

On the other hand, for the previous periods, with the exception of the 2018-2019 period, the demand projection coincides at least with the incremental ENFICCs with executed guarantees, taking as the most critical case the 2021-2022 period (including Hidroituango's FEO to satisfy the demand). This situation means that any contingency with any of the generating units, that have FEOs assigned for those terms, represents a very high risk of shortage to the SIN. In this way, it is necessary to buy the energy that is lacking in the market, which eventually represents an increase in the price of electricity to users.

5. CONCLUSIONS

Given the updated description of the scenarios that can be presented for the 2022-2023 period, supported by the CREG technical document and the update corresponding to the auction held in the first half of 2019, it is concluded that there is a significant risk of coverage in the 2020-2021 period for any of the proposed scenarios and for other periods (2019-2020 and 2020-2021) in the case of the absence of the Hidroituango FEOs, taking into account the high probability of occurrence of El Niño phenomenon for any of the periods under study.

On the other hand, even though for the auction held in the first quarter of 2019, the amount of FEO belonging to hydroelectric plants has significantly decreased (9.7%) with the associated decrease in the incremental ENFICC, replacing it with more reliable firm energy for periods of drought and with firm energy belonging to renewable energy sources, which effectively mitigates the impacts of the proposed scenarios for the period 2022-2023, the CREG took a rather conservative position by auctioning an amount of FEOs that was excessive in relation to the deficit that would potentially arise in a case of shortage, resulting in large amounts of surplus in relation to the two (2) proposed scenarios (8650 GWh-year and 1027 GWh-year respectively). Consequently, this energy must be sold again by the CREG to interested agents.

This situation represents additional charges to consumers due to the surplus amount auctioned with respect to the demand projection, and it may also represent greater economic losses depending on the price of the energy at the time when the sale is made.

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