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Situational analysis of the production of electric energy and its association with the energy overcapacity in the Peruvian electric market

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Abstract – In Peru, the energy market is continually affected by the different policies in this sector, the health crisis and the continuous social upheavals that are factors that drive an energy oversupply. The objective of this research is to carry out a study of the Peruvian electricity market to understand the factors that are related to the oversupply of energy generation in the Peruvian electricity market. To do this, the Peruvian electricity market, its characteristics, supply and demand for electricity generation are studied. In addition, the current legal framework is described in order to facilitate understanding of the operation of the corresponding activities. It is concluded that a decreasing spot price and an oversupply of generation make the entry of new base generators unattractive.

Keywords -- Electricity market, electrical demand, investment, energy oversupply.

I. INTRODUCTION

The generated electric energy is highly relevant to Peru's economy and the everyday activities of its people. Peru has different types of energy sources, which makes its energy matrix diversified [1], The electric power generated is highly relevant to the economy of Peru and to the daily activities of its people. Peru has different types of energy sources, which makes its energy matrix diversified [2].

COES planning studies collected information related to the integration of its recent projects that focus on generation as demand that alter projections that do not always end up being very close to actual results due to external and internal factors. It should be taken into account that the SEIN projects that the execution of works and mining investment would increase energy demand [3]; however, the energy behavior during the last decade presented periods with excess electricity supply [4], , reaching reserve values in the SEIN that are higher than the Reserve Margin established by the regulation of the sector and consequently there are generation units that do not obtain income by ability [5]. It must be remembered that, at the beginning of the decade, when economic growth was highest, some regions were affected by electricity service cuts due to an overdemand for the resource [6], which is far from the situation that occurred during the 2019 pandemic. where there was an energy oversupply, due to the suspension of industrial activities.

Therefore, in this research work, an analysis of the policies implemented in the energy sector is carried out in conjunction with the energy balance, taking information on the available resources and the energy demand that has been satisfied during the last decade to analyze the energy oversupply and its variation over time.

II. CONCEPTUAL FRAMEWORK

A. Relationships between the company and the state

In the electricity market, different economic agents operate, such as generating, transmitting, and distributing companies, which interact in the National Interconnected Electrical System (hereinafter "SEIN") in order to supply energy to both free and regulated customers nationwide.

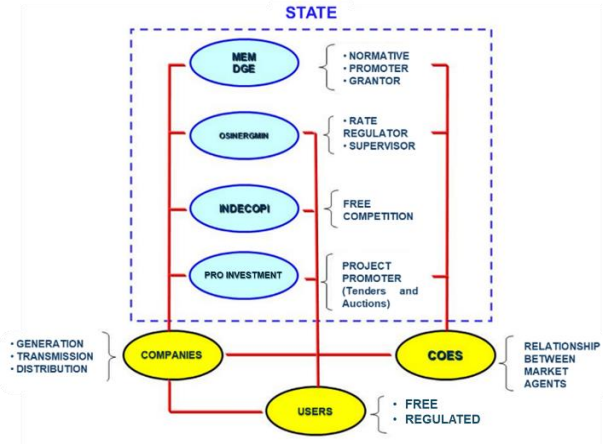

Fig. 1. Interrelationship of the electrical system and the actors involved in the electricity market

1) Supervisor of energy and mining investment organization - OSINERGMIN:

It is the regulatory and supervisory body of the electricity sector. Among its functions are the fixing of the rates applicable to regulated users and the monitoring of their periodic updating, the supervision of compliance with the legal provisions applicable to electrical activities in matters of safety, quality, service, among others [7].

2) COES:

The Economic Operation Committee of the National Interconnected System (COES) is a private entity, non-profit, and with legal status. It is made up of all the SEIN Agents (Generators, Transmitters, Distributors, and Free Users) and its decisions are mandatory for the Agents.

By law, COES is responsible for the following public interest functions:

a) Develop the Transmission Plan proposal for approval by the Ministry.

b) Develop the procedures regarding the operation of the National Interconnected System (SEIN) and the administration of the Short-Term Market, for approval by OSINERGMIN.

c) Ensure timely and adequate access of interested parties to information on the operation of the SEIN, transmission system planning, and administration of the Short-Term Market.

d) Ensure competitive conditions in the Short-Term Market.

e) Seek technological improvements that ensure the efficient fulfillment of its functions [8].

3) Free Users:

Users connected to the SEIN not subject to price regulation for the energy or power they consume (maximum annual demand greater than 2,500 kW).

4) Regulated Users:

Users subject to price regulation for the energy or power they consume (maximum annual demand equal to or less than 200 kW).

Users whose maximum annual demand is greater than 200 kW up to 2,500 kW have the right to choose between the Regulated User or Free User condition, complying with the requirements and conditions established in the Regulation. (Article 3 of Supreme Decree No. 022-2009-EM)

B. *Energy Demand*

1) Benefit of increasing electrical demand

According to the World Bank, in Peru, the percentage of the population living in poverty has decreased progressively, and this improvement in the quality of life of the population is related to the higher energy consumption per capita (Fig. 2), as can be seen by analyzing figure 2 showing this trend from 2005 to 2018. In 2018, the national consumption of electrical energy increased by 3% compared to 2017, resulting in an average annual growth of 4% over the last ten years.

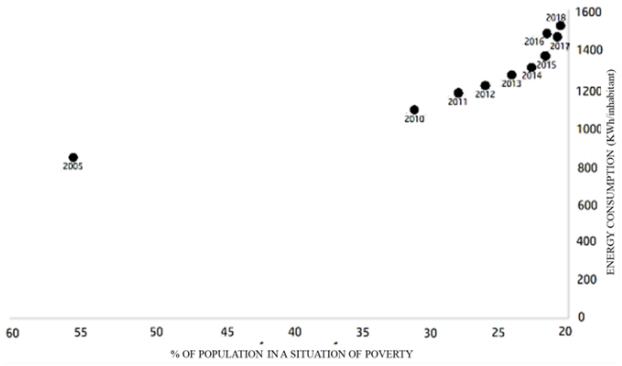

Fig. 2. Annual evolution of poverty and energy consumption in Peru

2) Evolution of Electricity Demand in Peru

Between the year 2008 and 2021, demand increased by 4.8%; however, various studies of the transmission plan carried out by COES projected demand growth to be at 7.9% between the years 2012 and 2022; 8% between the years 2014 and 2024; and 5.8% between the years 2016 and 2026, which, compared to the low demand, turned out to be projections far from the actual values of electric demand growth in the Peruvian electric market [5].

The aforementioned can be observed in the comparison of the different demand projections resulting from the transmission plans developed by the Economic Operation Committee of the National Interconnected System, in comparison to the actual historical demand, which, in the month of December 2019, amounted to 7018 MW, as shown in Fig. 3.

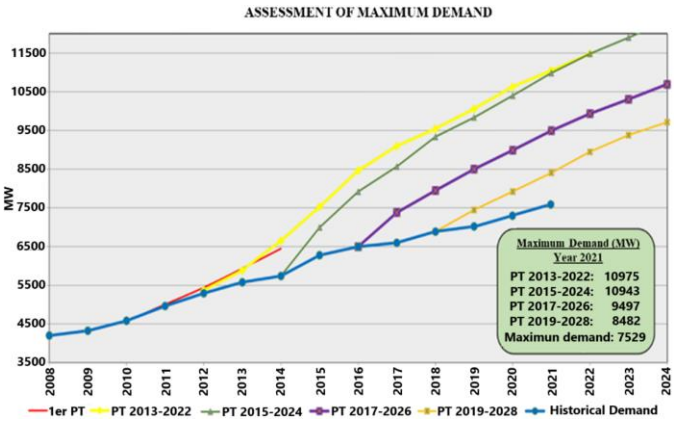

Fig. 3. Evolution of the electric demand compared to the forecast.

The evolution of electrical demand over time depends on many factors, with its main explanatory variables being population growth and the start of large industrial and mining projects, all equally driven by market agents' decisions.

In fact, the industry (including mining) has a significant share in energy consumption. In 2019, it represented 66% of the country's consumption, almost doubling in 9 years [1].

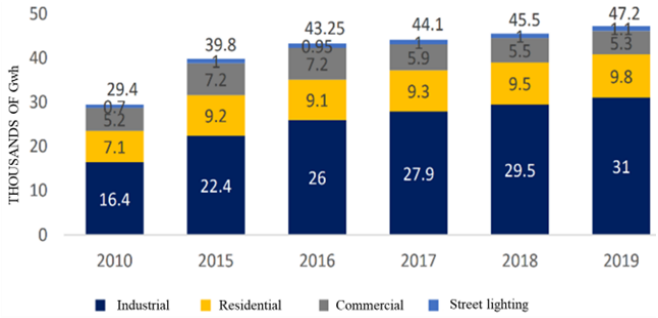

Fig. 4. Evolution of electricity consumption by type of use

3) The electric demand during the pandemic

Here is the series of actual daily demand in Peru and the demand estimated by the regression model for the adjustment periods (in blue) and the prediction periods in orange (See

Figure 5). By observing the daily reference demand obtained for 2020 through extrapolation of the adjusted model, it can be determined that the effect of the COVID-19 pandemic on Peru's electricity demand began on March 16, 2020, with a very significant decrease in consumption [9].

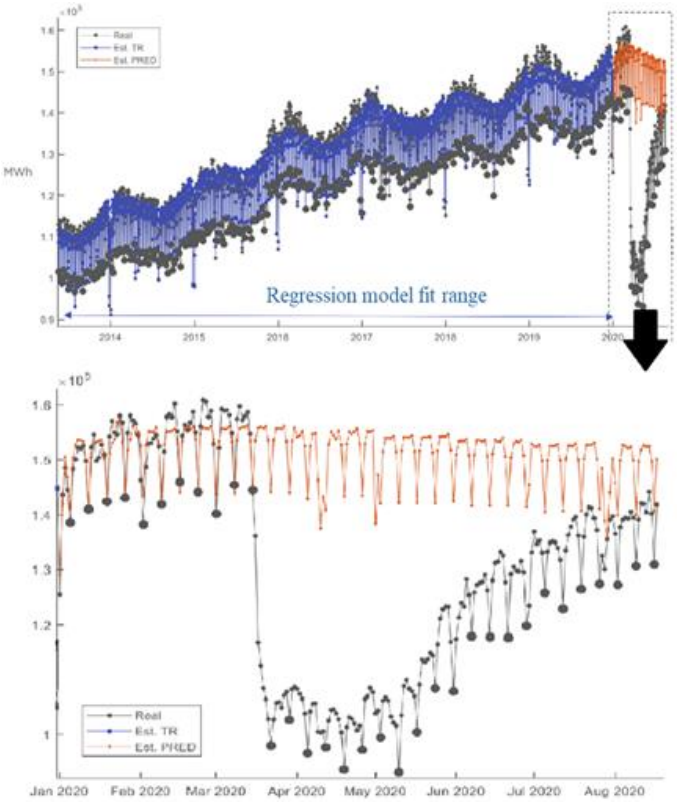

Fig. 5. Estimation of the expected daily demand for Peru

4)The electric demand for the mining sector

In Peru, mining represents 55% of the consumption of free clients and 34% of the national demand during 2021 (See Table 1), and seven generators supply over 90% of the power demanded by mining companies. The most relevant contracts in this sector were made by Cerro Verde with Electroperú (338 MW), Antamina with Engie (170 MW), Las Bambas with Engie (160 MW), Cerro Verde with Enel (140 MW), and Chinalco (130 MW) and Cajamarquilla (120 MW) with Kallpa [10]. However, during 2021, due to the health crisis caused by COVID-19, mining investment was paralyzed by delays caused by the State of Emergency, which resulted in an economic slowdown, leading to an extension of the duration of electrical oversupply and a continued decrease in spot prices [11]. Because of this, the Ministry of Energy and Mines (MINEM) formed the Electricity Sector Reform Commission (CRSE) with the aim of implementing comprehensive electricity reform.

TABLE I.
ELECTRIC POWER CONSUMPTION OF MINING CLIENTS

Mining Client	MW	%
Cerro Verde Mining	521.3	19.2%
Southern Peru	296.0	10.9%
Chinalco Mining Peru	211.0	7.8%
Nexa Resources Cajamarquilla	190.8	7.0%
Antamina Mining	170.0	6.3%
Las Bambas Mining Company	160.0	5.9%
Antapaccay Mining Company	145.3	5.4%
Shougang Hierro Peru	120.0	4.4%
Hudbay Peru	90.0	3.3%
Marcobre	84.0	3.1%
Yanacocha Mining Company	63.0	2.3%
Nexa Resources	54.0	2.0%
Anglo American Quevellaco	52.4	1.9%
Volcan Mining Company	49.0	1.8%
Others	505.4	18.6%

5)Decrease in investments and delays in project execution

The IPE projects that the Peruvian economy will grow by around 1.9% in 2022, the lowest rate in 13 years, not considering the decline recorded in 2020. This low growth would be explained by the imminent fall in private investment due to the deterioration of business confidence (See Fig. 6).

Fig. 6. Business confidence [12].

The uncertainty generated by political instability and the increase in social conflict has particularly affected the mining sector. In 2021, there were 147 active social conflicts in the country, the highest number since 2017. Of these, 43% are related to mining activity.

In recent years, a large number of electric generation projects have been added to the portfolio. However, due to pandemic restrictions, these have not been able to enter the market. This has resulted in installed capacity being much lower than expected during the 2019-2022 period, during which it grew by 609MW, which is lower than in previous years. Taking into account the report issued by Osinergmin in early 2023, at that time 62 generation projects were considered to be in the pipeline, of which only seven of these projects advanced significantly, and one is currently stalled with almost 50% progress [13].

In order to allocate electrical projects in different industries, the government leads and initiates tenders aimed at promoting the increase of new capacity to stabilize the market.

However, most processes have different goals that do not align with the goals set in other processes. In the end, the projections made in these processes were not met. All of this has resulted in an oversupply of generation capacity, affecting both the generation itself and the end users [14].

III. Energy Offer

A. *Legal Framework*

Legislative Decree No. 1002 This legislation, Legislative Decree for the Promotion of Investment for the Generation of Electricity using Renewable Energies, promulgated in 2008, aims to promote the use of Renewable Energy Resources (RER) to improve the quality of life of the population and protect the environment through the promotion of investment in electricity production.

Supreme Decree No. 012-2011-EM This regulation promulgated in 2011 approves the Regulation of the Promotion of Investment Law for the Generation of Electricity using Renewable Energies, with the objective of establishing the regulatory provisions necessary for the proper implementation of Law No. 1012, Supreme Decree.

Article 11 of Law No. 28832 contemplates a Short-Term Market (MCP), establishing that Generators, Distributors to serve their Free Users, as well as Large Free Users, can participate under the conditions and requirements established by regulatory means.

On August 31, 2019, the Supervisory Agency for Investment in Energy and Mining (OSINERGMIN) through a resolution ordered the COES to determine the firm capacity of RER power plants, specifically wind power plants, revoking the initial provision that established that these power plants had a firm capacity equal to zero [9].

In June 2021, Law 00990/2021-PE was implemented to complement Law No. 31429 in order to regulate the number of free clients through rules that prevent regulated users from migrating in large numbers to free clients [15], several people were looking to switch to free customers because they pay short-term costs in the free market, taking advantage of the regulations allowing it, causing an oversupply of electricity due to the continuous confrontation of generating companies to obtain free customers with whom they can enter into a long-term supply contract, which was reduced from 7.7 years to 4.5 years during 2020 [16], which caused the spot price to decrease constantly and free customers to seek renegotiation of shorter-term contracts to take advantage of the increasingly lower spot prices, which remained until June 2021 [17]. Later, law No. 27510 was modified in February 2022, which allowed for the creation of a Social Electricity Compensation Fund ("FOSE") generated by the surcharge on the billing of free users to be used to reduce the expenses of regulated users with few economic resources to avoid constant migration to free user (see figure 7).

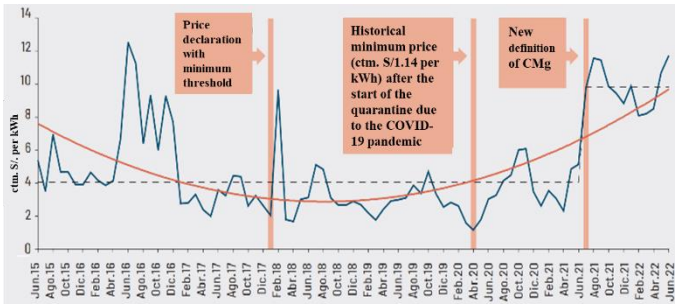

Fig. 7. Variation of the spot price

B. *Energy production using renewable energy resources:*

During the COVID-19 pandemic in Peru, the oversupply of efficient energy generation continued to trend from 2016 due to the decrease in mineral prices worldwide during those years. Efficient energy generation is achieved through sources other than coal, diesel, or residual [18]. Therefore, in this study, we will focus mainly on wind and solar energy, in order to later measure their impact on economic transactions within the short-term market. The energy production from January to December 2020 was 49,215.88 GWh, with 1,803.20 GWh coming from wind farms and 835.28 GWh from solar farms.

In Fig. 8 we can see the production from January to December 2020 of the wind farms with a total of 1,803.20 GWh, noting that the Wayra I plant has the highest production with 619.25 GWh, representing 34%.

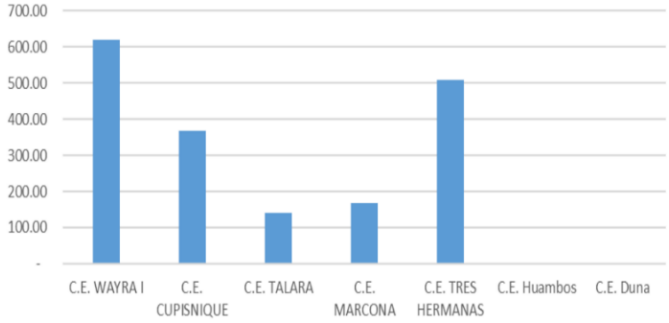

Fig. 8. Production from wind farms

The Fig. 9 shows the production from January to December 2020 of the solar power plants with a total of 838.13 GWh, noting that the Rubi plant is the highest producer with 435.53 GWh, representing 52%.

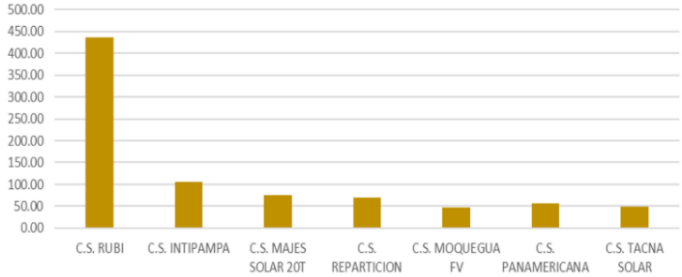

Fig. 9. Production of solar power plants

Recently, a considerable increase in the installed capacity of non-conventional renewable resources (solar, wind, biogas, and biomass) has been achieved, representing 7.7% at the end

of 2022. It is worth noting that generation based on these resources represented 75% of the effective power growth in 2022 [13].

C. *National Electricity Production*

The total production of electrical energy at the national level recorded for the year 2021, including Isolated Systems and SEIN, was 57,371 GW.h (see Table 2), and represented an increase of 8.8% compared to the previous year.

TABLE II.
National Electricity Production (GWh)

Energy Resource	January - December		Δ
	2020	2021	
Water	30 506	31 945	4,7%
Natural Gas	18 017	21 322	18%
Diesel/Coal/Residual	1 081	936	-13%
Bagasse/Biogas	535	561	5%
Wind	1 814	1 802	-1%
Solar	778	802	3%
Steam (Cogeneration)	2,70	2,73	1%
National total	52 734	57 371	8.8%

We will take the electricity production made in the month of December 2021 to know its distribution, in this case, 96% (4,800 GWh) was sold to the electricity market and 183 GWh (4%) was generated for self-use (See Fig. 10) [19].

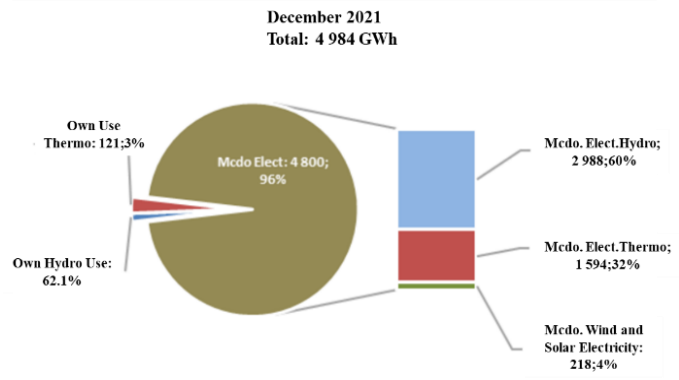

Fig. 10. National Electric Power Production in the month of December

Of the total electricity generation in Peru, the figure 11 shows the main generating companies, among which KALLPA GENERACION S.A., ELECTROPERÚ, ENGIE, and ENEL GENERACIÓN PERÚ S.A.A. stand out, which are currently working directly with companies in the mining sector.

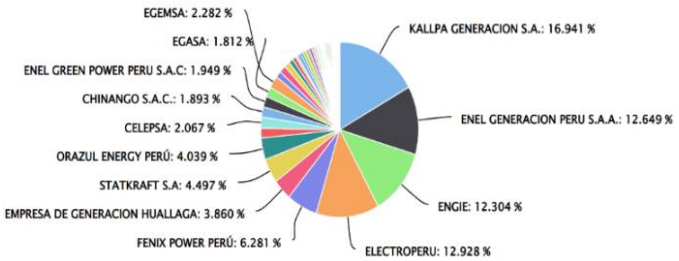

Fig. 11. Percentage of the total power output by each generating company.

IV. Results

The figure 12 shows the monthly income per power in the Peruvian electricity market, from post-pandemic wind plants. The economic recovery is appreciated due to the reduction of oversupply in this sector in which the highest income is received by the Wayra I wind power plant, followed by Tres Hermanas and Cupisnique; receiving the highest average income in the last 3 years with an amount of S/15,923,019 from the Wayra I plant, corresponding to the highest production recorded by this type of technology.

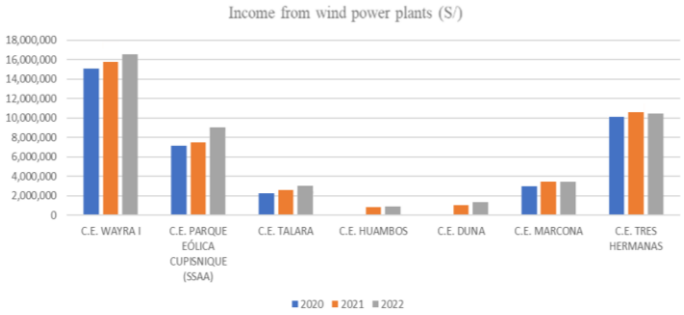

Fig. 12. Power generation from wind farms in the year 2020

The figure 13 shows the monthly income per power in the Peruvian electricity market, from solar plants during the post-pandemic stage. The economic recovery is appreciated due to the decrease in oversupply in this sector in which the highest income is received by the Rubi solar plant, followed by Intipampa and Moquegua Solar; The Rubí solar plant has received the highest average income in the last 3 years with an amount of S/ 306,172.

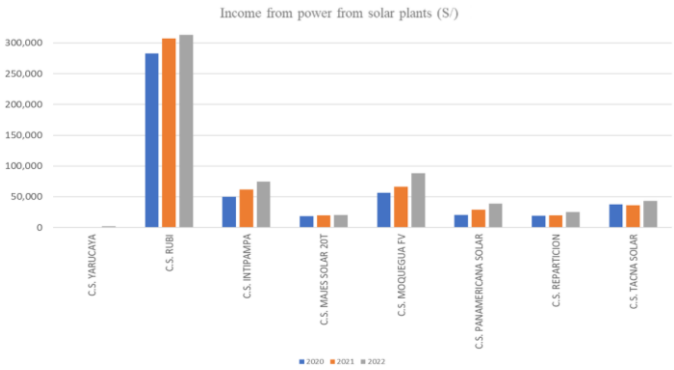

Fig. 13. Solar power generation from solar plants in the year 2020.

To calculate the costs of current technologies in Peru, equations (11), (12) and (13) from the study carried out by Racso [20] were used for both the capital costs (CAPEX) of the technologies of electricity generation as well as its energy costs.

In the case of photovoltaic solar plants, the results obtained were the following:

$$CAPEX_{Photovoltaic}=3\ 117{,}093\ USD/MW$$

$$78.15\ USD/MW \leq Energy\ cost_{Photovoltaic} \leq 98.4\ USD/MWh$$

In the case of wind power plants, the results obtained were the following:

$$CAPEX_{Wind}=2\,082{,}347\ USD/MW$$
$$42.92\ USD/MWh \leq Energy\ cos_{Wind} \leq 45.68\ USD/MWh$$

It can be seen in figure 14 that the annual generation of the SEIN during the year 2022 was 56,084 GWh, which compared to the year 2021 grew by 3.9% as a consequence of the increase in demand, which reduced the oversupply gap. This gap was reduced in 2023 due to growth projections.

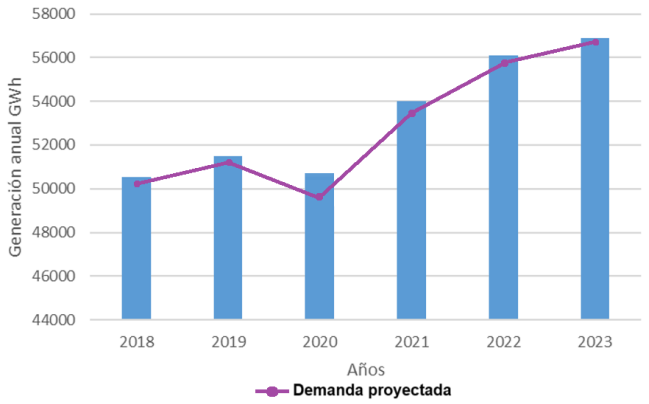

Fig. 14. Generation in the SEIN (GWh)

V. Conclusions

The delays and stoppages of major investment projects, mainly in the mining sector, and the increased reserve margin due to the suspension of certain industrial activities during the COVID-19 state of emergency in 2020 led to an expansion of electrical oversupply in the industry.

It has been determined that energy tenders are responsible for the growth of installed capacity in the electricity sector; however, the growth of supply has not kept pace with demand projections. In addition, the establishment of firm capacity in September 2019 has led to an increase in energy production in wind and solar plants, which has influenced the overcapacity of installed capacity. This has affected the economic transactions of wind and solar plants within the Peruvian electricity market, especially in the months of April and July 2020.

It can be concluded that aspects such as a decreasing spot price and an oversupply of generation make it unattractive for new base generators to enter into new contracts, especially if there are no positive demand projections.

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