

# Energy Efficiency Challenges in Ecuador in the Face of Increasing Electricity Consumption Per Capita

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## Abstract:

The objective of the study was to analyze the challenges of energy efficiency in Ecuador in the face of the increase in electricity consumption per inhabitant between the years 2013 and 2023. For this, an analytical study of documentary review was developed. The results show that the main challenges that Ecuador faces in the face of the increase in energy consumption have to do with the structural problems of hydroelectric plants, a lack of planning regarding demand and supply, in addition to the consequences of the corruption conflicts that affected the electrical sector. The need to think about the production of other energy alternatives through renewable resources that allow us to meet the demands of society without impacting the environment as has happened with the construction of hydroelectric plants is considered.

**Keywords:** hydroelectric, electric energy, renewable resources, environment, sustainable development.

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## INTRODUCTION

At a global level, nations consider the electricity sector as essential to achieve social development and well-being; it also promotes the economy as it allows investments to be made, favors the improvement and perfection of developing industries that generate jobs, contributing to achieving optimal levels in terms of quality of life (López-Meraz & López-Meraz, 2020).

For the electricity sector, the Government as well as representatives of the public and private sectors seek to define strategies to cover the needs and demands that they present, comply with the treaties and agreements for the protection of the environment and also achieve can establish due guarantees for citizens to access electrical energy through the approach of flexible policies in order to achieve sustainable and sustained development (Electric Corporation of Ecuador, 2018).

It is in this way that it is understood that the electrical system must remain in constant evolution to satisfy the demands of the markets, as a consequence of the interveners in the value or production chain that starts from the moment electricity begins its journey in the centrals through the located networks, crossing the transmitting entities that are in charge of transporting the electricity to the distribution points for its commercialization. This is a simple way of explaining how energy is capable of moving the world, being essential for technological development and innovation, as well as other forms of transformation worldwide, which is why it is considered a strategic sector. (Navarro, 2021). However, with the passage of time, there have been important approaches regarding the ways in which

energy is generated in order to not continue affecting the environment, which is why, through different agreements, the signing of important commitments has been achieved so that Nations transform the way they generate electricity by demanding that they stop using non-renewable resources and seeking the use of renewable ones (Vargas et al., 2020).

In the case of Latin America and the Caribbean, it has been possible to take advantage of the flow of large rivers, so the energy is generated through hydroelectricity, that is, renewable energy and complying with the postulates of an efficient energy matrix, which has made This region is characterized by being one of the most important energy producers in the world with 52% of total electrical energy production in the region, being a leader in low carbon emissions (Levy-Ferre et al., 2020). According to the Latin American Energy Organization and the International Renewable Energy Agency(2024)Of the four largest plants in the world, three are in Latin America, the most representative being Itaipú located between the countries of Brazil and Paraguay, whose capacity is 14 gigawatts, followed by Belo Monte in Brazil and Guri in Venezuela (Table 1 ).

**Table 1. Largest hydroelectric dams worldwide**

Country	Prey	River	Installed capacity (Gigawatts)	Dimension (m)
China	Three Gorges Dam	Yangtze	22.5	181 x 2,335
Brazil/Paraguay	Itaipu Dam	Paraná	14	196 x 7,919
China	Xiluodu Dam	Jinsha	13.9	286x700
Brazil	Belo Monte Dam	Xingú	11.2	90 x 3,545
Venezuela	Guri Dam	Caroní	10.2	162 x 7,426

Note: Prepared from International Renewable Energy Agency(2024).

Particularly in the case of Ecuador, it is the ninth country with the highest renewable energy production capacity in Latin America and the Caribbean with 5,394 megawatts, followed in first place by Brazil (175,562 MW), Mexico (31,683 MW), Chile (17,910 MW), Venezuela (16,906 MW), Argentina (15,076 MW), Colombia (13,435 MW), Paraguay (8,832 MW) and Peru (6,431 MW)(Statista, 2022). Ecuador has an important energy production in which its generation and the entire transmission and distribution belong to the State, it also maintains strategic relations with Colombia and Peru due to the possibility of exporting the energy surplus or to face potential crises within of the country in terms of deficiencies in its own generation. Even in 2018 there were exports of 233.5 GWh to Colombia and 22.13 GWh to Peru. For the year 2019, Ecuador's electrical energy production was 4838.70 MW, of

which 98.7% were destined for public service, with 44.8% originating from renewable sources.(Ministry of Energy and Mines, 2021).

However, in the following years the situation of the country's energy sector took a different direction and the Government's efforts, which had focused on strengthening the infrastructure of the most important projects in order to comply with the strategic purposes of the energy matrix and production were not possible due to irregularities due to the absence of technical environmental analyzes and the political-economic crisis that Ecuador has faced due to corruption cases.(Litoral Polytechnic School, 2024). This led to the country, from the end of 2023 and until mid-2024, facing one of the largest electricity crises, causing rationing at the national level, a situation that is also related to the demand for energy that has been increasing but the production The resource has not increased to the same extent due to the lack of investment and little attention to other forms of clean energy generation such as wind power, in which there was already a strong initial investment but no follow-up was given. Thus, investment in the sector was reduced in the last period corresponding to the previous 6 years with a failure of 84.6% of the electricity master planning.(Multiply Consulting, 2024).

It is precisely because of the above that the research aims to analyze the challenges of energy efficiency in Ecuador in the face of the increase in electricity consumption per inhabitant between the years 2013 and 2023, precisely prior to the crisis in order to understand the reason for the situation. that Ecuador faced in this last period.

## **METHODOLOGY**

The research has an analytical nature from which an understanding of the electricity sector in Ecuador and its challenges regarding its efficiency in the face of the increase in consumption per inhabitant is sought, for which a diagnosis is made from 2013 to 2022. To For this purpose, the bibliographic and documentary research method was used, that is, obtaining primary information through the review of different sources such as results reports, publications, statistical data, official documents referring to the Ecuadorian electricity sector, among others to fulfill the objective. investigative. In addition, the quantitative method is used to analyze the statistical and numerical information. This methodological combination allows the triangulation of information obtained from various sources and the processing from different approaches, giving depth and value to the results (Molero-Jurado et al., 2023).

## **RESULTS AND DISCUSSION**

### **RESULTS**

#### **Analysis of the Ecuadorian electricity sector**

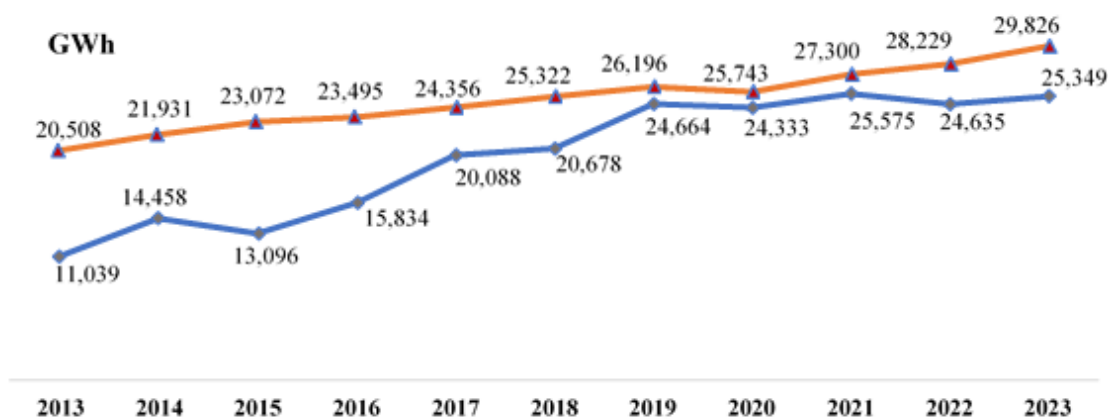
Between the years 2013 to 2023, there was a significant population increase in the country of at least 11.45%, meaning that more than 17 million Ecuadorians were registered, in the same way there was a significant growth in GDP reaching 69,089 million dollars (13.4% ), but it could also be observed that the increase in energy consumption per inhabitant went from 1,304.5 KWh to 1,680.0 KWh per inhabitant (Table 2), only the year 2020 recorded different figures due to the Covid pandemic crisis. - 19 and in which specific measures were taken at the industrial, productive level and in all companies in the country that justify their lower consumption(Ministry of Energy and Mines, 2023).

**Table 2. Electrical energy consumption per inhabitant in Ecuador**

Year	Electrical consumption (GWh)	Population (thousands inhabitants)	Per capita of consumption (KWh/Hab.)
2013	20,508	15,721	1,304.5
2014	21,931	15,978	1,372.6
2015	23,072	16,233	1,421.3
2016	23,495	16,479	1,425.7
2017	24,356	16,726	1,456.2
2018	25,322	17,002	1,489.4
2019	26,196	17,275	1,516.4
2020	25,743	17,441	1,476.0
2021	27,300	17,528	1,557.5
2022	28,229	17,630	1,601.2
2023	29,826	17,754	1,680.0

Note: Prepared from the Ministry of Energy and Mines(2023).

The energy needs, always increasing, have led governments to make efforts to increase generation capacity (not always successfully), in this context, below you can see the energy generation capacity in the analyzed period ( figure 1). It is evident that there was an increase of 56.5% in the generation capacity between 2013 and 2023, going from 11,039 GWh to 25,349 GWh (nominal capacity). In this context, it is also interesting to analyze that the years of greatest increase (investment ) are 2016 and 2018, with stagnation from 2019 onwards.



**Figure 1:History of production vs. electricity consumption in Ecuador**

Note: Prepared from the Ministry of Energy and Mines(2023).

On the other hand, energy generation sources have privileged the use of the country's water capacities, since the geography and abundance of water allow projects of this type, even some of them in cascade, that is, power plants. energy generation that uses the waters of the same river in a phased manner, are developed effectively, and are also sources of clean and renewable energy. In this sense, it should be noted that the use of alternative energy sources such as wind or solar remains limited to some marginal projects and whose contribution is not greater at the moment. Energy sources based on fossil fuels, extracted from oil such as Diesel, have also increased, although to a lesser extent compared to water sources (Table 3).

**Table 3. Energy supply in Ecuador (kBEP)**

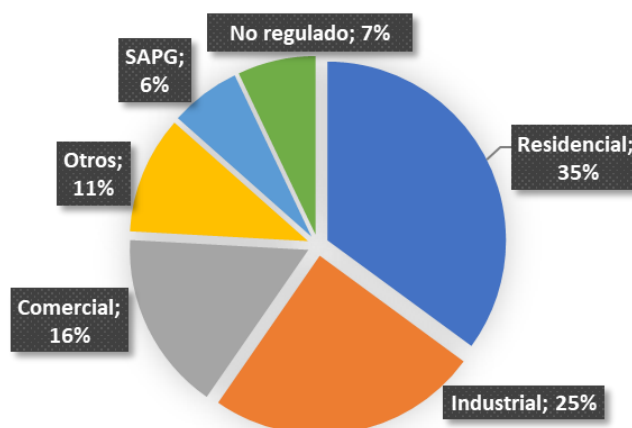
Year	Oil and derivatives	Natural gas	Renewable*	Electricity**
2013	85,063	6,587	10,359	392
2014	93,790	6,734	11,133	489
2015	89,408	6,661	12,134	289
2016	83,419	7,261	13,915	-198
2017	84,175	6,802	16,827	-120
2018	82,852	6,153	16,882	-90
2019	87,833	5,584	19,525	-1,128
2020	74,913	4,902	19,168	-675
2021	86,865	5,191	19,631	-99
2022	91,639	4,483	18,876	169
2023	97,621	4,088	19,376	481

\*Hydroenergy, wind, solar and other primary energy are considered.

\*\*Import and export of electrical energy.

Note: Prepared from the Ministry of Energy and Mines(2023).

Now, regarding the distribution of electrical energy consumption in Ecuador, it is mainly residential with 35%, followed by industrial with 25% of consumption (figure 2).

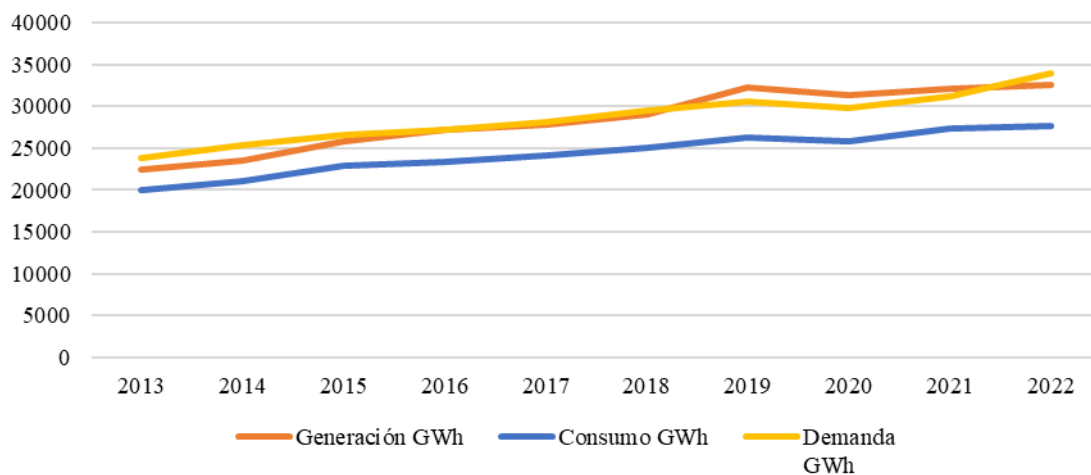


**Figure 2: Distribution of electricity consumption in Ecuador in 2023.**

Note: Prepared from the Agency for the Regulation and Control of Energy and Non-Renewable Natural Resources(2022).

### Challenges of the electricity sector in Ecuador

It is important to note that the demand for electrical energy is not necessarily equal to consumption, since demand is what households, productive sectors and other consumers require for the normal development of their activities, while consumption is the use that different types of users use the energy they have available, in this sense, a first challenge in the provision of electrical energy is to close the gap that exists between demand and generation, which is growing again after having managed to remain controlled. (Figure 3).

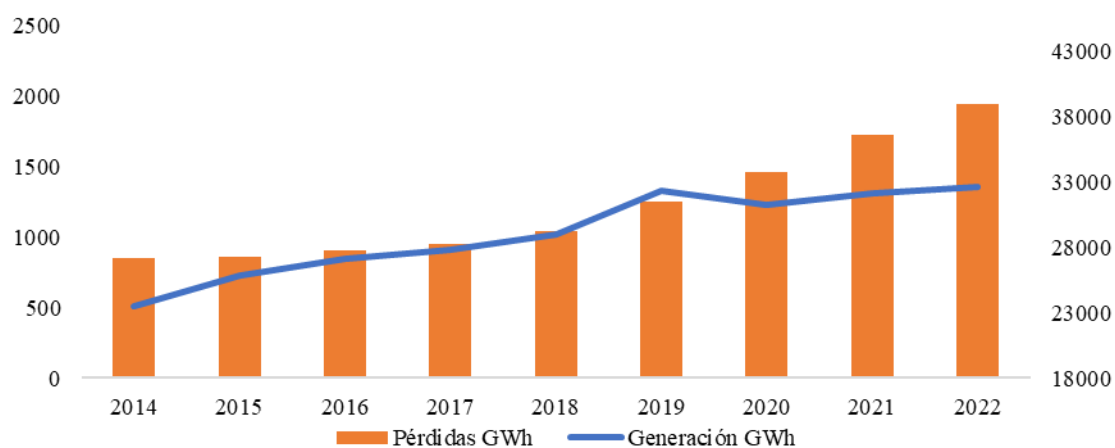


**Figure 3: Demand Vs generation of electrical energy.**

Note: Prepared from the Agency for the Regulation and Control of Energy and Non-Renewable Natural Resources(2022).

It can be seen that in 2016 the gap between demand and generation was closed, that is, the country managed to generate what the users or the electricity market needed, later a surplus was even achieved in the years 2019 and 2020 (in In the latter case, the Covid-19 pandemic had a lot to do with the decrease in demand), but in 2022 there will already be a deficit of 4%, which means that the needs of the electricity market are not being met, in In this context, it is expected that the needs to import energy from neighboring countries, look for alternative generation sources such as barges or even ration energy, are emerging measures that must be taken as they are not able to cover the deficit that arises and that, given The lack of investment in new generation projects will predictably tend to increase.

Another important challenge is to mitigate losses already in the context of distribution and consumption that occur due to inefficiencies of distribution companies or due to energy theft in urban centers. The following graph shows how the increase in energy generation between 2014 and 2022 is 39%, while the increase in distribution losses is 128%, which gives an idea of the dimension of the problem and that it is not has done a lot to control it (Figure 4).



**Figure 4: Generation Vs losses of electrical energy.**

Note: Prepared from the Agency for the Regulation and Control of Energy and Non-Renewable Natural Resources(2022).

The next challenge that will be analyzed is to close the gap that exists between the nominal capacity and the effective capacity of the electrical energy generation system, since for different reasons, ranging from lack of maintenance, dry periods (lack of rain and consequently of water in the reservoirs), lack of fuel supply, etc., the country has never managed to generate 100% of its theoretical capacity, since, on average, it is able to generate at 92% of capacity.

In this way, it is observed that Ecuador has stagnated its electricity generation capacity and that its increase is not sufficient to supply the population increase and the changes in living conditions due to technological advances and improvements in socio-economic conditions. of the population, in this sense it is essential that the country increase its generation capacity urgently and as a priority, also overcoming the inefficiencies that prevent it from generating at full capacity and being able to overcome losses in the distribution stage.

It is important to note that the Constitution of the Republic of Ecuador(2008)declares in its article 313 that energy in all its forms is part of the so-called “strategic sectors” for which the Ecuadorian state reserves the right to administer, regulate, control and manage it. In this same sense, article 314 of the same legal body establishes that the state is responsible for the provision of electrical energy services, in addition to the establishment of prices, as well as its regulation and control. Although the aforementioned articles of the Constitution, in theory, guarantee the supply of energy at adequate prices, in practice they have become entry barriers to private investment that could contribute to solving or at least mitigating the aforementioned problems and analyzed in previous paragraphs, in this context, the last challenge that is stated and analyzed, constitutes a challenge that is not technical but legal and even political and this makes it perhaps the most important of all.

Overcoming statism and the declaration of “strategic sectors” that in practice become a state monopoly is perhaps the most important challenge in terms of achieving sufficient energy at reasonable prices that truly covers the growing needs of the population. Ecuadorian.

### Energy efficiency programs in Ecuador

Taking into account that energy efficiency is the proper use of energy resources, it is understandable that the good use of the resource is sought without this representing a detriment to its productive quality.(Guerra & Guillén, 2021). Faced with this, it is important to mention that in Ecuador various strategies have been proposed to save electrical energy and achieve a decrease in dependence on the resource, which in turn translates into an improvement in economic terms for consumers of electrical service. reduction in pollution rates, and the total use of energy so that it is not used unnecessarily.

Energy efficiency programs have been promoted by the Government through transformations in the socio-cultural behavior of citizens and consequently with the technological reality in order to align with the principles of the energy matrix. Among the most important programs is the “Electrification Master Plan 2012-2021” in which changes are proposed in the country's energy matrix to cover the electricity needs through the generation of hydroelectricity, complying with the fundamentals of energy efficiency. To this end, the strengthening of existing hydroelectric projects and the development of others, including the following, was proposed (Table 4).

**Table 4. Projects in the Ecuadorian hydroelectric sector**

Project	construction company	Country of origin
Manduriacu	Norberto Odebrecht SA	Brazil
Toachi Pilaton	China International Water & Electric Corp., Inter Rao, Celec-Hidrotoapi.	Ecuador, Russia, China
Mazar - Doubts (Sorrel)	China National Electric Engineering Company	China
Blower	Gezhouba Group Company-Fopeca SA	China
Coca Elbow Sinclair	Sinohydro	China
Delsitanisagua	Hydrochina SA	China
Quijos	China National Electric Engineering Company	China

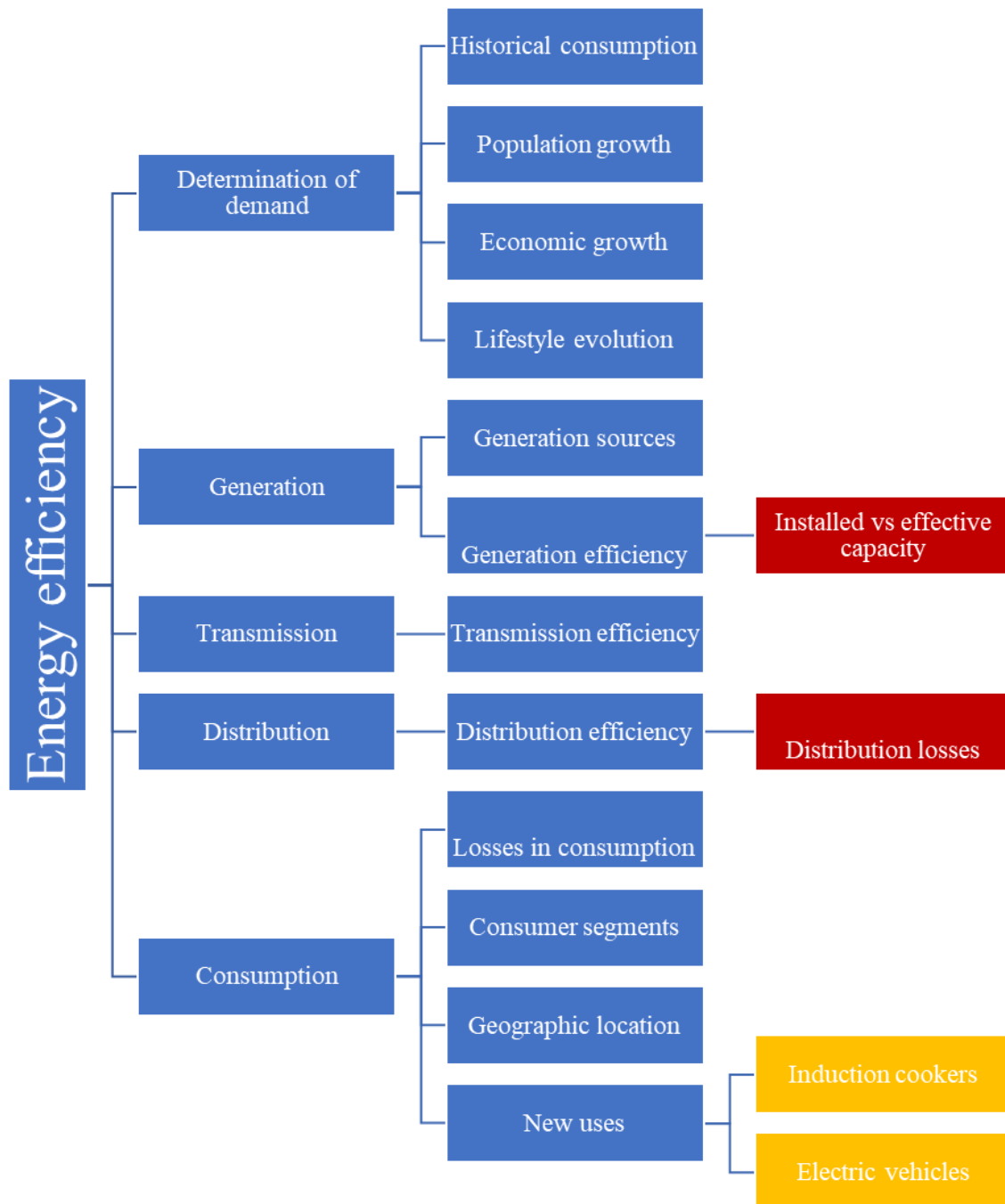
Note: Prepared from Corporación Eléctrica del Ecuador(2017)

These projects, as is evident, have been under the direction of China, so it is questionable whether the country actually maintains a mutually beneficial relationship with said nation. These hydroelectric plants are directly dependent on water from rivers, such as Coca Codo Sinclair supplied by the Coca River, but in the case of the plants known as reservoirs, their structure allows the accumulation of water, supplying according to demand. The most relevant reservoirs in the country are Paute, Mazar, Agoyán, Pucará, Marcel Laniado, Baba(Gómez-Ponce, 2023).

Now in this context, the programs to promote energy efficiency focused on replacing induction cookers that had been promoted years ago as a promising proposal for homes but that did not manage to be successful and involved significant electrical consumption, nor was it achieved. to carry out the

replacement of the diesel engine with electric ones in the shrimp sector. On the other hand, in different cities, savings and efficient consumption programs are promoted in homes and companies but without much success. And in contrast, in recent years, the use of environmentally friendly vehicles such as motorcycles and electric cars has been promoted, including increasing free charging points at different points in cities nationwide.(Manzano-Mantilla, 2022).

Finally, the factors associated with energy efficiency are presented schematically in Figure 5.



**Figure 5: Generation Vs losses of electrical energy.**

## DISCUSSION

Satisfying the needs of citizens in terms of improving their quality of life clearly implies an increase in the demand for electrical energy, so it is important to focus on development since this is undeniable, which is why it is necessary to consider the use of renewable energy as an important way to meet the requirements of society. And it cannot be depleted because it leads to insecurity in the cities, important economic repercussions at the national level, lower production, problems in the educational and tourism sectors, etc.

However, in this scenario, Ecuador has had to face important problems that have conditioned its development and have been related to acts of corruption, reducing the effectiveness of the implemented policies and also citizen confidence in the justice system. This problem has important components from historical events to political and cultural events and clearly economic interests.(Rojas-Asuero et al., 2020). This is how the Ecuadorian electricity sector has also been immersed in anomalies that have overtones of corruption in the value chain and in the process to regulate and operate the system, due to the contracts for millions of dollars that have been signed and for which Cases of bribery, overpricing, etc. have arisen, with citizens being the affected ones as the resources come from them through the collection of taxes fundamentally.(Naranjo-Silva, 2024).

Precisely the most relevant hydroelectric projects that have been cited in the investigation and that are part of the so-called energy matrix, are part of irregular processes in their contracts and that have been the subject of investigation. One of the most questionable has been Coca Codo Sinclair, rising to a cost of \$2,245 million dollars that was financed through credit with the country that was also in charge of its development, China. Despite its million-dollar cost, after an investigation carried out in 2019, considerable flaws were identified in it with cracks that would represent a new expense for the country of tens of millions of dollars, despite being the most promising project for Ecuador. that would even lead the nation to export energy(Álvarez-Chiriboga, 2020). Added to this is that the country has faced crises related to the climate, politics and economy, directly influencing the electricity sector.(Miranda, 2019).

On the other hand, reforms have been proposed in the electricity sector to change productive structures, but as has been identified in this research, they have not been viable not only because of the problems mentioned, sinceArévalo-Urdiales(2022)indicates that they are also due to the financial, administrative and technical deficiencies that have occurred in energy production, the costs that have not been covered, high commercial and technical losses, which is why the sector is not attractive for investors and generate and transmit energy.

Faced with the above, Manzano-Mantilla(2022)makes an important consideration regarding the need to plan urban and rural electrification needs and that hydroelectric projects be considered based on them, in addition to incorporating the private sector in the electricity distribution and generation process and making adjustments in electricity rates. service, since electrical energy should be seen not as a service, rather it is a right, which is why modernization is necessary through technologies that seek the optimization of natural resources.

## Conclusions

In coherence with the objective of analyzing the challenges of energy efficiency in Ecuador in the face of the increase in electricity consumption per inhabitant between the years 2013 and 2023, it is possible to indicate that electrical energy in the country is one of the sectors considered strategic and in What is possible complies with the fundamentals of environmental efficiency, which is why it has been considered a right rather than a service that citizens access and it is precisely for this reason that this sector has had to modernize and find a way to optimize renewable resources.

However, this has not been enough to guarantee the needs that the country has in terms of electricity coverage, since the consequences of the acts of corruption, the political and economic problems that Ecuador has faced have had an impact on the electricity sector, preventing its development and adequate attention in terms of maintenance of infrastructure and correct consideration of the required annual production. This led to the crisis of 2023 and 2024 where rationing was presented at the national level, affecting the country considerably and even leading the Government to consider the need to purchase energy from neighboring countries to solve the needs that arise. Although energy production is the responsibility of the State, it is necessary to consider the participation of the private sector, since the electricity sector is not advancing or consolidating because it is not able to cover the differences between real values and those subsidized, on the other hand There is no interest from investors due to the unstable situation of the nation, to which is added the current economic crisis, which has an impact on the security that can be granted to the sales or concession processes.

It is evident that electricity consumption per inhabitant has increased between the years 2013 and 2023 and this will continue to increase, due not only to population growth but also to the lifestyle of people characterized by the technological presence dependent on energy. One of the challenges of the electricity sector is to meet the needs of society efficiently and with quality, seeking sustainable alternatives. Associated with this are other important challenges to achieve the development of its energy potential and that is to seek a reduction in the investment required, to make room for strategic partners or actors to get involved, to be able to have an adequate system for estimating the needs of the resources efficiently as well as their availability, energy efficiency policies are also needed, a tariff analysis in which the costs of generating the resource and its transmission are correctly considered, to mention the most relevant.

It is also necessary to take into account the required technical studies as well as those of an environmental nature, since hydroelectric plants have a significant impact on the environment and must be analyzed before, during and after their execution, they even significantly affect the communities. surrounding areas so it is necessary to maintain constant social monitoring.

Finally, it is possible to indicate that the crisis in the electricity sector in Ecuador derives from past and current events, which have violated it, but the current Government has the responsibility and challenge of seeking alternatives that return stability and can align itself with the essential principles. efficient energy matrix. It is necessary to analyze the viability of carrying out new projects with renewable energy alternatives to hydroelectric, not only because of the cost it represents, also because of the damage it generates and even because of the dependence on the water resource, which, as has been shown, can be scarce due to climate changes, but other resources available to the country could

be used. In this way, it may be possible to meet the increase in demand and supply of electricity, in addition to requiring an improvement and expansion in the distribution and commercial system, thereby ensuring better provision of the service without losses and with adequate profit margins. collection.

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